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1926—1927.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Life Member shall be a member whose service to the Association entitles him to special recognition by the Association.

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An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

A Corporate Member shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

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This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.

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Photo by Bachrach.

FRANK E. WINSOR,
President of the New England Water Works Association.
1926-1927.

New England Water Works Association

ORGANIZED 1882.

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This Association, as a body, is not responsible for the statements or opinions of any of its members.

PUBLIC OWNERSHIP AT BRIDGEWATER, MASSACHUSETTS, AND THE IMPROVEMENTS MADE AFTER PURCHASE BY THE TOWN.

BY FRANK A. BARBOUR.*

[*Read November 10, 1926.*]

Starting in the early morning of December 10, 1924, a fire destroyed three buildings of the State Normal School in Bridgewater, Massachusetts — causing damage estimated at one million dollars and endangering the lives of some two hundred and fifty students housed in one of the burned dormitories.

It was generally agreed that the magnitude of the loss was due to inadequate water supply. Ample fire-fighting apparatus was available, as Brockton, West Bridgewater, and Middleboro had responded to the need, but such equipment was of little use with a water system which would not supply two standard fire streams. That the fire was prevented from spreading farther was due to water pumped from Campus Pond, a small artificial pool in an adjacent park, which lasted just long enough to forestall a general conflagration in the town. The catastrophe was a clean-cut example of the danger in failing to provide a water supply sufficient for adequate fire service.

Back of the failure of the water system to meet fire service requirements there is a history which is perhaps sufficiently interesting and suggestive to merit recording.

In November, 1886, the town voted not to build a water works; on June 9 of the following year it entered into a contract with the Bridgewater Water Company, which had been duly organized under Chapter 192, Acts of 1887. The contract ran thirty years from date of completion of the works shown on plans to which reference was made. A detailed schedule of consumer rates, which was not to be exceeded for the term of the contract, was included; the town was to pay thirty dollars per year per hydrant, and the contract specified the size of pump units, the dimensions of standpipe, and referred to plans of the distribution system. It stipulated that the mains should be "of cast iron, ranging from eight to two inches in diameter, laid not less than four and one-half feet below the surface of the ground, and

* Consulting Engineer, Boston, Mass.

when so laid shall stand a pressure of three hundred (300) pounds to the square inch of inside surface." Such descriptive adjectives as "proper, complete, substantial" and even "perfect" are much in evidence in the contract, but no definite requirement of adequate fire service appears. The charter stipulated that the company might make a contract to supply water for domestic, manufacturing, and other purposes, and for the extinguishing of fires — "as may be agreed upon," but the contract did not impose any definite obligation to furnish a supply adequate for fire service.

In general the contract was such as would be accepted by a town desirous of obtaining a water supply, but unwilling to act for itself, and therefore content to enter into an agreement which did not specify definitely adequate fire service, and which recognized the laying of mains smaller than good practice would permit. And thus it naturally followed that the system as built was not in the beginning, nor at any later time during the thirty-seven years of company ownership, ever capable of providing reasonable fire protection.

Chapter 192 of the Acts of 1887 authorized the water company to supply both the towns of Bridgewater and East Bridgewater, and a similar contract was entered into with both communities. The supply works and standpipe were located in Bridgewater.

In 1889, or within two years after the initial construction of the company plant, Bridgewater appointed a committee to confer with the creditors of the company with a view to the purchase of the works, and from that time until 1925 such committees, with the same objective, were periodically in existence. So far as the records show, competent engineering advice was never sought in any of these negotiations.

The fact that within three years after the date of incorporation of the company the plant was in the hands of the bond-holders, suggests that the financing of the project followed the quite frequent practice of the early days of water companies, by which the money invested did not much exceed the return from the sale of bonds. In the present instance probably but little more than the funds derived from the original one hundred thousand dollar bond issue were available for the first construction. As the original cost somewhat exceeded one hundred thousand dollars, some accounts were not paid, and as the immediate revenue did not meet operating expenses and interest, the bond-holders foreclosed.

By Section 8 of Chapter 192 — Acts of 1887 — the two towns, or either of them, were granted the right to take at any time "by purchase or otherwise the franchise, corporate property, and all the rights and privileges of said corporation on payment to said corporation of *the total cost* of its franchise, works and property of any kind, held under the provisions of this act, including in such cost interest on each expenditure from its date to the date of taking, as hereinafter provided, at the rate of seven per centum per annum. If the cost of maintaining and operating the works of said corporation shall exceed in any year the income derived from said works by said

corporation for that year, then such excess shall be added to the total cost; and if the income derived from said works by said corporation exceeds in any year the cost of maintaining and operating said works that year, then such excess shall be deducted from the total cost."

"If the town or towns and the company could not agree on a price, then, upon a suit in equity by said town or towns, the supreme judicial court shall ascertain and fix such total cost under the foregoing provisions of this act." Obviously, the interpretation of this prescribed method of determining the amount to be paid for the works, if taken, is not so simple as might appear at first glance. Apparently eliminating going value and the intangible factors in valuation, it emphasized all the difficulties of determining first cost from inadequate records, of interpreting "income," and — leaving depreciation to be inherited by the town, it did not create a condition tending to a high standard of upkeep. Perhaps fair to both parties in the earlier years, with good cost accounts available, it became later increasingly less practicable, but also — due to the rising cost of labor and materials, particularly as a result of the war — it became more favorable to the town in its elimination of reproduction cost as a factor in determining value.

The charter also provided that if either town took the plant, it should give one year's notice of its intent to purchase to the other town, and that it should continue to furnish water to the other town in quantity equal to that supplied by the water company at the time of purchase. No provision was made in the original act for the purchase by either town of only that part of the plant within its own borders — the right to purchase apparently being limited to the total plant. At no time did either town invoke the authority delegated to the Supreme Court to determine the amount to be paid the water company, and the negotiations with the company generally ended in the impass created by the condition that the company would not name a price which no one acting for the town had a right to accept in advance of a town meeting, and which such a meeting might refuse to approve.

And thus the company continued inadequately to serve both towns until March, 1913, when, under authority of Chapter 111 of that year, East Bridgewater purchased that part of the plant within its borders, paying therefor the sum of one hundred thousand dollars — the company agreeing to continue to furnish water from the supply works in Bridgewater for three years at eight cents per thousand gallons. Chapter 111 apparently repealed certain sections of Chapter 192 — including that by which the price to be paid for the company's plant was to be based on actual cost plus interest less net earnings. In effect it nullified Bridgewater's right to take the plant without additional legislation, and complicated the legal situation as regards the future obligations of Bridgewater to East Bridgewater, if the remaining portion of the plant, which included the supply works and standpipe, were taken.

Obviously, with a contract covering hydrant rental and consumer rates based on 1887 price conditions of labor and materials — and running thirty years to 1918 — the company had small chance of financing from earnings the very substantial additional works necessary for adequate fire service, and likewise, without a previous agreement as to new rates, which would guarantee a fair return on the investment, the sale of additional bonds or stocks was difficult, and perhaps impossible.

Throughout the many years of intermittent negotiation the position taken by the company indicated an endeavor to force the town to buy. On the other hand, the town argued that the company should make the improvements necessary for adequate service, and contended that the earnings had been sufficient to make this possible.

On December 6, 1922, a new factor in the possible solution of the problem was introduced by a petition of certain citizens of Bridgewater to the Department of Public Utilities, alleging inadequate fire service, and asking the department to require the company to make the necessary improvements. A hearing on this petition was held on January 17, 1923. On May 3, the department addressed a letter to Bridgewater expressing sympathy with the town's desire to obtain better service but stating that — as the issues involved had raised many important legal questions — the board was not yet prepared to make a finding. On May 23, 1923, the town by vote instructed the selectmen to petition the Department of Public Utilities to require action on the part of the company in the provision of better fire service, and a hearing was held on June 12 — following which the water committee of the town advised the department by letter that it had gained the impression that "the department may favor purchase by the town, but the sentiment of the citizens is against such action, and that the question at issue is not purchase, but to have the water company conform with the terms of its franchise." Up to this time there had been no real engineering investigation of the situation, and on July 7, 1923, the Department of Public Utilities requested the Department of Public Health to investigate the plan for the water company, and to report the improvements necessary for adequate fire service with an estimate of the cost.

After an investigation under the direction of Mr. A. D. Weston, which included fire flow-tests, the results were reported to the Department of Public Utilities in November, 1923. In reference to fire service, it was reported that throughout the greater part of the town not more than two good streams, and in many places not more than one good stream, could be obtained. At only three points were three streams possible and two of these were points adjacent to the standpipe where fire protection was least required. The report outlined the improvements necessary and estimated the cost at $182 850.

On January 1, 1924, the company, without authority, raised its rates — charging sixty dollars for hydrants, and increasing the old meter schedule somewhat less than 50 per cent. over those of the original contract. This

action resulted in a petition from the town on January 21, 1924, to the Utilities Department, thus placing before that department both the question of fair rates and that of adequate service, which was still pending.

On March 7, 1924, the Department of Public Utilities approved the increase in consumer rates but ordered that the hydrant rate be reduced to thirty dollars until such time as the water company had completed certain improvements suggested by the department. On the same date the department dismissed without prejudice the petition of the town that the company be required to furnish an adequate supply of water, but suggested that the company might make a start on the improvements recommended by the State Department of Health, by providing additional wells, and laying a larger main from the standpipe to the town, at a total cost of thirty thousand dollars —"in return for which the company will be entitled to make a reasonable return on the investment." No order to this effect was, however, issued. The company did not undertake the improvements recommended by the department, another petition was filed by the town on June 28, and another hearing held on July 22, but nothing resulted, and thus the stage was set for the Virginia block fire in January, 1924, and the larger Normal School conflagration on December 10, of the same year, involving an estimated loss of around one million dollars, or four times the cost of rebuilding the water-works system.

The loss of the Normal School, with its economic importance to Bridgewater, and the position of the State authorities that the provision of adequate fire protection must be a condition precedent to rebuilding, at once served to focus a bad situation which for more than thirty-five years had persisted without remedy.

On December 20, the town appointed a committee with authority to employ engineering and legal advice to make a thorough investigation of what was necessary to the requirements of an adequate water supply, and to report its conclusions to the town on January 24, 1925. This committee retained the writer's firm as engineers, and Mr. Philip Nichols as attorney.

The first question in the minds of the committee was as to the relative merits, from the standpoint of the town, of building an entirely new system and of purchasing and rebuilding the old plant. The importance of quick action was obvious, and on January 15, a report was submitted by the engineer to the committee covering the design and cost of a new plant, and also of reinforcing the old plant so as to render equivalent service.

The general basis of the design in both cases was a fire supply of 2 500 g.p.m. in the higher value district, coincident with an ordinary consumption of 500 000 gal. per day, with storage adequate to maintain this service over a period of six (6) hours, and to provide at the end of that time a minimum hydrant pressure of twenty (20) pounds per sq. in., and in the outlying districts a fire service ranging from 1 000 to 1 500 g.p.m.— except at the extreme ends of some few lengths of unsupported six-inch mains, where 500 to 600 g.p.m. would be available.

In estimating the reinforcement necessary in the old system, all pipes four inches or less in diameter were disregarded, and all larger pipes were credited with a coefficient of 80, or with approximately two-thirds of the discharge capacity of new pipe — the latter assumption being based on an analysis of Mr. Weston's flow-tests, and on observations of frictional loss made by representatives of the writer's office at several points in the system.

The estimated cost of a complete new system was $522 000, and of reinforcing the old plant to equivalent capacity for service, $302 000, or a differential of $220 000.

On the basis of actual cost plus interest, plus or minus operating deficits or earnings — as specified in the original act of 1887 — the amount which would be due the company was again indicated, on the approximate analysis possible in the time available, to be somewhere between $210 000 and $240 000.

Coincidently the attorney had rendered several interesting opinions: — that the town by obtaining the necessary legislative authority could construct an entirely new plant without violating any constitutional right of the water company, and without providing any compensation to the company for injury to the value of its franchise; that the water company had never been definitely obligated by its charter or contract to furnish a supply adequate for fire service; that Chapter 111, 1913, authorizing the sale to East Bridgewater of a part of the company plant probably revoked Bridgewater's right to purchase the remaining plant on the basis of cost plus interest, as provided in the Act of 1887; and finally, that without additional legislation Bridgewater had not the right to take the company plant.

The engineers reported that the value of the plant — if determined by trial — might range from $175 000 to $225 000, depending on the legal conditions controlling the method of determining value.

Both the attorney and the engineer favored purchase by negotiation at a reasonable figure, rather than the construction of an entirely new plant. Taking into account all the conditions, including the probable loss by Bridgewater of its right to purchase at cost plus interest, less net operating income, and particularly giving weight to the great value of an early decision in order that the town might go forward in the work necessary to remove the existing fire risk, the engineers recommended the amicable purchase at any figure below $225 000, rather than undertake the construction of new works.

Armed with these conclusions of its attorney and engineer, the committee approached Mr. Eugene N. Foss — principal owner of the water company — and offered him $175 000, which he accepted.

At the meeting of January 24, the town voted unanimously to purchase the company plant for this sum, and to petition the legislature for authority to issue $500 000 to cover the purchase and necessary improvements. The act was signed by the governor on February 12, and on February 21, the

town voted to accept the legislation. On April 25, the contracts for the new water works were let. Thus in the reflex from the Normal School conflagration — quick, decisive action had replaced the ineffectiveness of thirty-five years. It is not necessary further to point the moral, but several interesting questions naturally arise, among which, not the least interesting, is that in reference to the position of the Department of Utilities in the case of a water company, admittedly not furnishing adequate service, and apparently unable to finance improvements on such rates as the town would agree to, and where the town is unwilling to take over the plant of the company.

The system as taken over on March 21, 1926 — while utterly inadequate for fire service — was of value as a framework about which to construct works of adequate capacity and safety against derangement. It consisted of 34 driven wells and a brick pumping station located on the bank of the Matfield River, a standpipe of 275 000 gal. capacity (25 ft. x 80 ft.) on Sprague's Hill, and a distribution system of 18.45 miles—55 per cent. of which was 4-in. pipe or smaller diameter. Pumping equipment included two 450 g.p.m. triplex pumps, driven by 50 h.p. oil engines, which required heating by the external application of a torch in starting, and which threw oil in such quantities that the adjacent wall and floor were saturated. This, in combination with a timber mezzanine floor, which supported the air pumps, constituted a very substantial fire risk. The standpipe, with its usual draw-down of 45 ft. during the night, furnished neither quantity nor pressure adequate for fire service. Of the 82 hydrants all but seven had only 4-in. valve openings and a 4-in. run to the main. The hydraulic capacity of the distribution system was such that with the standpipe drawn down in the early morning, the available fire draught ranged from 125 g.p.m. in the outlying locations to 250 g.p.m. in the business center.

In general terms, the obviously necessary improvements included the redevelopment of the wells, the elimination of the fire risk at the pumping station, the provision of additional storage, and — most important — the reconstruction of the distribution system. This work involved nothing of particular engineering interest, and will therefore be described briefly.

In redeveloping the wells the accumulated sand was removed by wash-pipe with water taken from the adjacent main, and subsequent pumping with gasoline-driven diaphragm pump until the well cleared. At an expense of approximately $600, the yield — with two pumps running — was increased from 575 g.p.m. to 890 g.p.m. and the suction lift decreased from 21 in. to 15½ in.

The revamping of the pumping station included the adoption of electric drive for the existing triplex and air pumps, with a gasoline engine for auxiliary service, the removal of all wood construction except the roof, and the general overhauling of the station. Electric energy is furnish d at 2 300 volts by the Brockton Edison Company, and stepped down to 550

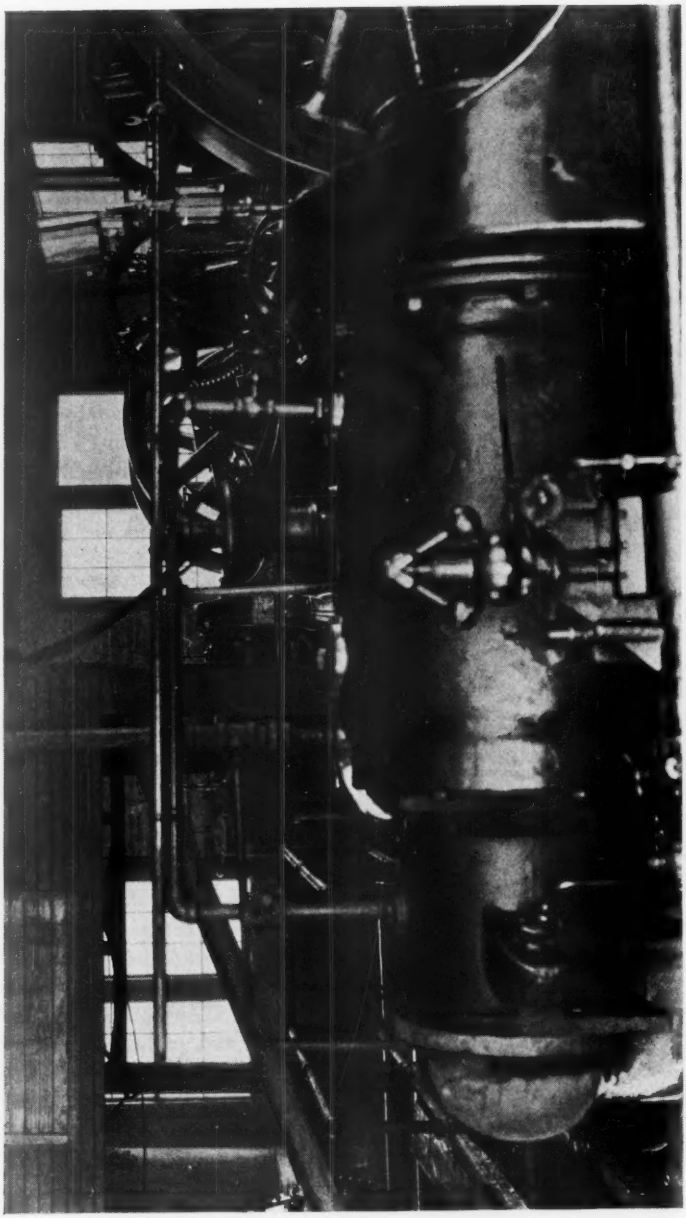


FIG. 1. — PUMPING STATION — CONDITION BEFORE IMPROVEMENT.

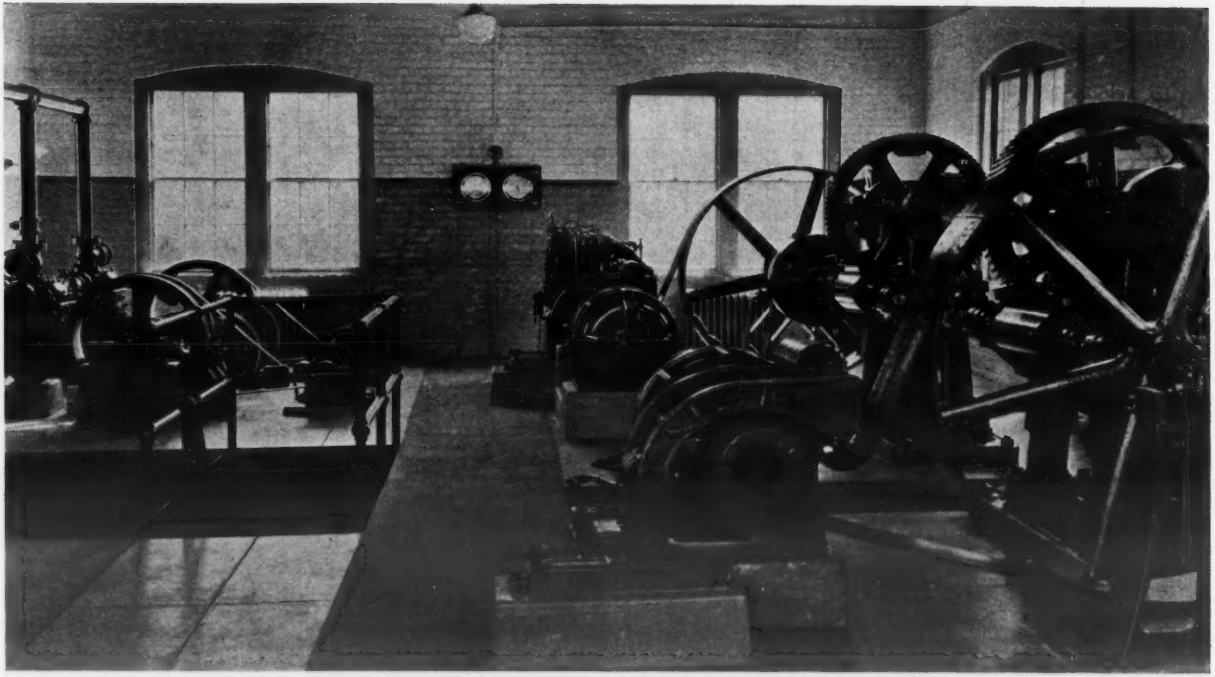


FIG. 2. — PUMPING STATION — AFTER INSTALLATION OF MOTOR-DRIVE.
(Taken from same point as Fig. 1.)

volts for the 50 h.p. motors which are connected with the pumps through a short belt drive of the "Pulmax" type, and new semi-helical gears. This drive may be of some interest to members; the semi-helical gears are practically silent.

The air pumps are automatically started and stopped by electrical switches actuated by a float in a supplementary air tank superimposed on the old air tank or sand chamber. The improvements at the pumping station, including the structural renovation of the building, were made under contract by the F. A. Mazzur Company.

Additional distribution storage capacity was provided by a standpipe of 990 000 gal. (40 ft. x 105 ft.), located on Great Hill, on the opposite side of the town from the old standpipe. It was constructed of flange-grade steel, with tensile stresses in shell plates limited to 12 000 lbs., and rivet shear to 9 000 lbs. per sq. in. Vertical joints were of the "butt and double-strap type"; caulking was on the outside, except the bottom and lower ring; the cement-sand cushion method of bedding the bottom was used, with mortar carefully packed for a distance of 18 in. from the outside edge, on removal of the shims when several courses of the shell rings were in place. Riveting up to the seventh course was done by the "bull" or gap riveter. Above this elevation pneumatic hammers were used. Subsequent tests indicated that such leaking rivets as developed were in the plates where the gap riveter was employed. The foreman attributed this to the use of oil fuel in rivet heating, because of the greater scale formation, and claimed that with a coal fire the gap riveter had always proved satisfactory. As to whether this is true or not, the writer leaves the answer to others, but so far as his experience goes, the use of the "bull" has not proved as satisfactory as the hammer. The first test for leakage also disclosed considerable leakage along and below the joint between the first and second rings, where the caulking changes from the inside to the outside. All such leakage was satisfactorily stopped by additional caulking.

The tank was given a shop-coat of red lead and two coats of Detroit Graphite paint. The total cost of the standpipe, including foundation, was $35 975, or 3.64 cents per gal. of capacity, and of the steel work alone, $28 454, or 2.88 cents per gal. of capacity. The standpipe was constructed by the Pittsburgh-Des Moines Steel Company.

The reinforcement of the distribution system included a 14-in. connection from the standpipe to a loop of 12-in. and 10-in. pipe encircling the high-value district; a new 10-in. connection with the pumping station; 8-in. and 10-in. mains in the industrial area along the railroad; and 6-in. mains in all outlying districts previously served by 4-in. pipe, which latter in all but a few cases were left in place for domestic service, and frequently cross-connected with the new mains. A total of 12.35 miles of new pipes were laid, of which 6.4 miles are 8-in. or larger. The present total length of pipe in service is 29.2 miles, of which 5.1 per cent. is 4-in., unparalleled by larger pipe.

In trying to find subject matter of general interest, reference may be made to the fact that all the pipe laid at Bridgewater was furnished, under contract, by B. Nicoll and Company, from the foundries of the Pont-à-Mousson and associated companies in France — the primary reason for the purchase of this material being a differential of $3.70 per ton below the lowest bid from an American foundry. The Bridgewater experience with this pipe is entirely satisfactory to date. There were a considerable number of split spigots, largely confined to the earlier shipments, which in total amounted to 120 lengths out of 5 034 lengths, or 2.4 per cent. All but fourteen of these imperfect pipes were caught by the inspector before laying. After laying, the testing of the mains developed fourteen cracked pipes, which were removed at the expense of the pipe contractor. These damaged lengths were generally found by the leakage tests to which all mains were subjected, and which required that under a pressure of 150 lbs. the leakage should not exceed 200 gal. per day per in. of diameter per mile of pipe. Sixty per cent. of all pipes laid were tested before backfilling and all visible leakage stopped; where conditions would not permit testing before backfilling, the rate of leakage under the specified pressure was accurately measured, and if greater than the limit specified, the cause of the excess was searched out, the pipe exposed, and the necessary repair made. Subsequent to these tests no pipe breakage has occurred, and the small night consumption to date continues to indicate the tightness of the system. Of the pipe laid, 75 per cent. was Class B, A. W. W. A. standard, which was used wherever the static head from full standpipe was less than 200 ft. Some trouble was caused in the earlier shipments by failure of the contractor to deliver the special castings coincidently with the straight pipe. This was remedied by purchase at the expense of the contractor of the necessary castings from American foundries. In the later shipments this did not occur and the specials furnished were particularly smooth and clean.

The French pipe is smoother and better coated than the average American product. Its phosphorus content amounts to 1.6 per cent. as compared with 0.9 per cent. in the American iron — a condition which would naturally be expected to increase the brittleness of the metal under shock. Certain other characteristics of the French iron are, however, of collateral interest. Its tensile strength ranges around 27 500 lbs. per sq. in., or substantially higher than is customary in American practice, and it will, in transverse tests easily meet the requirements of a progressive relation between flexure and breaking load, suggested by the committee on revision of standard specifications some years ago, and which Dr. Moldenke reported to be impracticable in the American foundries. It does not necessarily follow, however, either that the higher phosphorus materially lessens the resisting qualities of the pipe against shocks of the character which are transmitted hydraulically in water systems, or, on the other hand, that the higher French test-piece results indicate corresponding value of the metal in the pipe.

All pipe were laid with Leadite, and it may be of interest to refer briefly to the alternate bids received on laying with lead, which were requested in order to measure for the benefit of the water commissioners the relative economy of the two methods. In both cases the item for pipe laying included hauling, handling and jointing of the pipes, and the furnishing of the jointing material. Thirty-three bids were submitted by eighteen contractors, of whom thirteen submitted proposals on both sections of the distribution system. Of the twenty-six bids thus submitted, four showed savings in this item by the use of Leadite, ranging between 40 and 50 per cent. of the price named with lead joints, six between 30 and 40 per cent., six between 20 and 30 per cent., six between 10 and 15 per cent., and four a saving of approximately 5½ per cent. The twenty-six bids showed an average saving, in the minds of this representative group of contractors, of 22 per cent., while the proposal of the lowest, and accepted bidder, showed a saving of 49.1 per cent. The work in both sections was done by G. Ferullo Company of Boston.

It may be also of interest to note that the use of the special jointing compound did not preclude the making of the test for leakage within a reasonable period of time. In any case where such tests are undertaken, it is necessary to fill the pipe slowly and to wait long enough to insure that all air is removed, and this time was apparently sufficient for the leadite joints to become tight enough to meet the specified maximum of 200 gal. per inch-mile per day.

Valves were purchased under contract, from the Ludlow Valve Mfg. Company, and hydrants from the Darling Valve and Mfg. Company. After completion of the work a fire flow-test was made on December 14, in the vicinity of the Normal School, with ten hose lines drawn from five hydrants. With standpipe 10 ft. below full, the maximum total rate of discharge, estimated from size of nozzle, length of hose line, and observed pressure, was slightly in excess of 2 500 g.p.m., with a resulting drop in pressure of ten pounds, and a residual at the hydrants of 56 lbs. per sq. in. On January 1 and 2, additional hydrant flow-tests with pitometer measurement of discharge were made at eight different points in the system. The results indicated a capacity for direct fire service, with the standpipe 10 ft. below full level, ranging from 2 300 g.p.m. in the business center to 660 g.p.m. on the outskirts — with 50 lbs. residual pressure at the hydrants.

From these results it is evident that the adopted basis of design — namely, 2 500 g.p.m. in the high-value district for six hours, with a minimum hydrant pressure of 20 lbs. at the end of that time — has been fulfilled by the system as built.

In connection with the fire flow-tests, an endeavor was made to develop by quick shutting-off of fire streams the maximum water hammer possible under fire conditions. The greatest excess registered was 13 lbs., due to the rapid closing-off of approximately 1 000 g.p.m.

Contractor			*No. 1*		*No. 2*		*No. 3*		*No. 4*		*No*
Section			*1*	*2*	*1*	*2*	*1*	*2*	*1*	*2*	*1*
Item and Quantity.	*Section 1.*	*Section 2.*									
Earth excavation	16,000 cu. yds.	14,500 cu. yds.	1.10	.98	1.00	1.20	1.10	1.10	1.00	1.00	1.35
Rock excavation	50 cu. yds.	50 cu. yds.	8.00	8.00	12.00	12.00	15.00	15.00	5.00	5.00	5.00
Laying cast-iron pipe with lead joints:											
4 inch	100 lin. ft.	150 lin. ft.	.35	.35	.35	.35	.30	.30	.20	.20	.20
6 inch	12,400 lin. ft.	6,300 lin. ft.	.35	.35	.35	.35	.40	.40	.30	.30	.21
8 inch	9,200 lin. ft.	8,820 lin. ft.	.40	.40	.45	.45	.45	.50	.40	.47	.27
10 inch	3,400 lin. ft.	4,620 lin. ft.	.45	.45	.55	.55	.50	.75	.63	.68	.30
12 inch	2,900 lin. ft.	950 lin. ft.	.50	.50	.60	.65	.55	.85	.80	.90	.36
14 inch	.....	3,400 lin. ft.	...	.55	...	.85	...	1.00	...	1.63	...
Setting fire hydrants	69	31	7.00	7.00	6.00	6.00	10.00	10.00	5.00	5.00	10.00
Removing fire hydrants	29	13	7.00	7.00	5.00	5.00	10.00	10.00	10.00	10.00	5.00
Concrete masonry	10 cu. yds.	10 cu. yds.	20.00	20.00	22.50	22.50	20.00	20.00	10.00	10.00	22.00
Laying cast-iron pipe with leadite joints:											
4 inch	100 lin. ft.	150 lin. ft.	.15	.15	.30	.30	.19	.19	.17	.17	.15
6 inch	12,400 lin. ft.	6,300 lin. ft.	.15	.15	.30	.30	.26	.21	.27	.27	.17
8 inch	9,200 lin. ft.	8,820 lin. ft.	.20	.20	.40	.40	.29	.38	.37	.43	.19
10 inch	3,400 lin. ft.	4,620 lin. ft.	.25	.25	.45	.45	.36	.66	.60	.65	.21
12 inch	3,900 lin. ft.	950 lin. ft.	.30	.30	.50	.60	.43	.70	.77	.87	.27
14 inch	.....	3,400 lin. ft.	...	.35	...	.80	...	.88	...	1.60	...

ADDITIONAL WATER SUPPLY TABULATION OF BIDS

No. 5		No. 6		No. 7		No. 8		No. 9		No.10	No. 11		No. 12		No.13	No. 14		No. 15		No.16	No.17	No.18	No.19
1	2	1	2	1	2	1	2	1	2	1	1	2	1	2	1	1	2	1	2	2	2	2	2
1.35	1.35	1.50	1.15	1.80	2.00	1.60	1.60	1.65	1.65	1.90	1.75	2.00	1.56	1.47	1.75	2.00	2.00	2.62	2.71	1.20	1.00	1.75	2.20
5.00	5.00	12.00	12.00	7.00	7.00	15.00	15.00	8.00	8.00	6.00	7.00	7.00	8.50	8.00	12.00	5.00	5.00	11.50	11.50	12.00	6.00	6.00	10.00
.20	.20	.28	.28	.25	.25	.25	.25	.30	.30	.24	.15	.15	.38	.36	.35	.25	.25	.31	.31	.22	.30	.24	.30
.21	.23	.36	.36	.30	.30	.35	.35	.35	.35	.30	.20	.20	.43	.40	.50	.50	.50	.46	.46	.27	.40	.30	.30
.27	.27	.46	.46	.35	.35	.40	.40	.45	.45	.35	.27	.27	.63	.60	.60	.70	.75	.55	.55	.35	.55	.35	.365
.30	.32	.58	.58	.45	.45	.45	.45	.55	.55	.40	.35	.35	.70	.66	.85	.90	.90	.60	.60	.45	.70	.40	.44
.36	.41	.71	.71	.50	.50	.60	.60	.75	.75	.45	.40	.40	.81	.77	1.00	.92	1.00	.73	.73	.55	.85	.45	.50
...	.40	...	.86	...	.70	...	1.00	...	...	...	...	2.00	...	.85	...	...	1.65	...	.97	.72	1.15	.50	.61
0.00	10.00	6.00	6.00	4.00	4.00	6.00	6.00	10.00	10.00	6.00	50.00	50.00	50.00	50.00	2.00	7.00	6.00	7.50	7.50	7.00	12.50	6.00	25.00
5.00	5.00	10.00	10.00	4.00	4.00	8.00	8.00	20.00	20.00	8.00	35.00	35.00	20.00	20.00	5.00	15.00	15.00	10.00	10.00	7.00	15.00	8.00	12.00
2.00	22.00	30.00	30.00	5.00	5.00	15.00	15.00	15.00	15.00	20.00	25.00	25.00	18.00	18.00	4.50	15.00	15.00	15.00	15.00	21.00	20.00	20.00	12.00
.15	.15	.22	.22	.17	.17	.15	.15	.25	.25	.18	.13	.13	.26	.24	.35	.20	.23	.20	.20	.20	.25	.18	.27
.17	.17	.24	.24	.18	.18	.25	.25	.30	.30	.23	.18	.18	.28	.26	.53	.38	.40	.29	.29	.22	.35	.24	.27
.19	.19	.30	.30	.21	.21	.30	.30	.38	.38	.28	.25	.25	.46	.44	.58	.60	.65	.33	.33	.28	.50	.28	.34
.21	.21	.38	.38	.25	.25	.35	.35	.45	.45	.32	.33	.33	.48	.45	.82	.80	.80	.38	.37	.36	.65	.32	.41
.27	.27	.48	.48	.30	.30	.45	.45	.65	.65	.35	.38	.38	.58	.52	1.07	.85	.85	.42	.42	.45	.80	.35	.47
...	.29	...	.59	...	.36	...	.80	...	1.40	...	...	2.00	...	.55	...	...	1.50	...	.60	.60	1.10	.40	.58

TABLE I.
N. E. W. W. ASSOCIATION.
VOL. XLI
BARBOUR ON
PUBLIC OWNERSHIP
AT BRIDGEWATER

The total expenditure by the town in the improvement of the water system approximates $250 000.

The work was initiated and largely completed under the very able direction of William H. Bassett, H. Loring Jenkins and Joseph W. Keith, Water Commissioners.

THE STUDY AND EXTENSION OF DISTRIBUTION SYSTEMS.

BY LAURENCE C. HOUGH.*

[*Read January 12, 1927.*]

Of all the phases of the general subject of the delivery of water for fire and domestic purposes, probably that of distributing it to the ultimate consumer within the city or town limits is the one which receives the least attention. The literature on the subject is relatively small.

Distribution systems are rarely ever designed — they are usually in the class with "Topsy" who, "just growed." Much thought and work has been expended upon the collection of water — its purification, and its delivery to the vicinity of the centers of population — but there the intensive study of the subject seems to have languished. These items involve the expenditure of large sums of money in a short space of time. Ample provision for future growth is made in capacity and large capital expenditure is completed for a generation. It is only in cities of very rapid expansion, like Los Angeles and Detroit, where anything like a comprehensive plan of the distribution system is developed and carried out. The purpose of this paper is to point out the economic need of systematic development.

The original water system in a given community usually consisted of a line of small main leading from a pump or pond down the main street and past the bulk of the houses. As the village grew, branches were taken off of the main line, and soon a "tree system" of dead ends was formed. Gradually these were connected up and the grid thus evolved. As Bill Jones or Tom Smith built a new house and "wanted water," the main nearest him was extended. Sooner or later the grid of 4-in. or 6-in. pipe became overloaded, and a larger main was needed to maintain pressure. Thus the trunk main appeared. Too often these trunk mains followed paving jobs. A street was to be repaved and a larger pipe was put in to obviate the necessity of future breaking of the street surface. Usually the 4-in. or 6-in. main was replaced with an 8-in. or 12-in. main without serious regard to the probable future demand upon it.

Our waste investigations during the past 30 years throughout the United States and Canada have brought to light much interesting data on the behavior of trunk mains, and point to the necessity of careful study in their design and maintenance. A few examples will illustrate the point:

(1) In one city in the state of New York, there was a reduction in pressure during the daylight hours. To remedy this, a new 20-in. main was laid from the source of supply through the heart of the city. Contrary to expectations, the pressure situation remained unchanged. Numerous

*District Engineer — The Pitometer Company.

tests were made, but the trouble could not be located. After heated recriminations, the matter simmered down and the job was charged up to profit and loss.

In 1924, during a water waste survey, two 20-in. gates were found closed. When these were opened, much desired pressure was immediately obtained. Evidently all gates had been closed for a final pressure test of the line when it was laid. After the test apparently all of the gates had been opened *except* the 20-in. gates which fed the city. Why? Nobody knows. That was several years ago. The point is that a perfectly good 9 000 or 10 000 ft. of 20-in. main, representing an investment of $50 000 to $75 000 lay idle in the ground for several years and did the work of a 6-in. or 8-in. distribution main.

(2) In Baltimore, Maryland, a 48-in. main was found to have reversals of flow during the day, where one direction was normally expected.

(3) In Toledo, Ohio, a 30-in. main had been proposed to supply water to a point where the fire supply was deficient. There was already a 30-in. loop from the pumping station and from a 36-in. conduit feeding the business center of the city. Our trunk main survey disclosed the fact that the water was feeding all the way back through the 30-in. loop to the business center. It was found that when the proposed new plant is put into operation, the present 30-in. loop can be placed into full operation and the proposed 30-in. main will be unnecessary. The saving in this case amounted to almost a quarter of a million dollars which would otherwise have been buried with no particular advantage to the system.

(4) In Trenton, New Jersey, a 20-in. main was proposed to feed a certain section which apparently was inadequately supplied. A trunk main survey and distribution study based thereon, showed that this main would not accomplish the result desired, and the saving of its cost amounted to $40 000.

(5) In Harrisonburg, Virginia, some 14 miles of 10-in. main brings water from a mountain stream to the town. Here the surplus not used, flows into a small reservoir which alternately fills at night and lowers in the day time. As the demand for water grew to exceed the capacity of the supply main, a booster pump was installed at the town limits to maintain pressure. This pump operates about 12 hours, from 7 A.M. to 7 P.M. It was found that when the pump was started the flow at that point was immediately increased by the capacity of the pump. Within two hours however, the rate had slumped off to only 10 per cent. over the normal gravity flow. When the switch was pulled and the pump stopped, the water would flow backward toward the mountain, actually reversing the motion of the pump for several minutes.

(6) In one Massachusetts town, the supply is pumped through some 15 miles of force main varying in size from 20-in. to 8-in. The standpipe on the far end would not fill, and it was proposed to lay one and one-half miles of 24-in. main to reduce the friction. But before doing this they decided to investigate.

First we constructed a theoretical profile of the hydraulic grade line using the Hazen and Williams Tables for the known age of the various lengths of various sizes. Then the elevation of the hydraulic grade was measured at each change of size in the main, and the actual profile was obtained. The two curves were found to be practically parallel except in one short stretch of some 800 ft. of main. Here the slope went skyward. By spending about $300 to clean this stretch, the friction was brought down to normal and this mile and a half of 24-in. main is not even thought of at present.

Most state laws provide that no profit be made through the sale of water by municipal plants. In the frenzy to give water at the lowest possible rate, only maintenance costs are used, and no provision is made for depreciation. Sinking funds may be maintained to retire the bonds when they mature, but there is no reserve fund to retire the physical plant when it matures. Consequently, large sums must be spent at intervals to rehabilitate the distribution system. This custom is facilitated by the relative ease with which municipal bonds can be marketed.

A better plan is to put down on paper what extensions and improvements will probably be needed in the future, estimate their cost and set aside each year a portion of this amount, then actually lay a portion of the mains called for by the plan. Too often a department will attempt to lay up a fund for extensions, but as soon as the credit balance with the city treasurer builds up to a sizable figure, the eagle eye of some political sage lights upon it, and you may trust him to find some way to get at this money and spend it on a new fire station or such. The writer has in mind one town where the bonds of the new city hall are being retired almost entirely by the annual so-called "surplus" of the water department; and another where certain park areas were turned over to the water works for maintenance, simply to use up its depreciation fund. The point is to put this money underground where it cannot be reached. The problem of the water works superintendent then resolves itself into how best to "salt away" his surplus so that in the future years it may best serve the community.

The Distribution System contains two major elements:

1. The *Trunk Mains*, which, except in the case of very large cities, may be taken as mains of 12-in. diameter and larger; and

2. The *Distribution Grid* of 4-in., 6-in., 8-in. and 10-in. mains.

The accepted layout of trunk mains seems to be the loop, encircling the high value area and with numerous cross connections.

Predicting future growth is always a hazardous undertaking, especially in these days of rapidly shifting centers of population. The more one deals with statistics on population, the less reliable they appear. Data on population can be obtained from many sources, such as Federal and State census, school census, the data from gas and electric companies, the lists of registered voters, etc. The only way to arrive at a reasonable prediction seems to be to plot all available data on one sheet of paper, and then

use your best judgment. Intensive study is best made by wards. In some cities, ward lines are changed periodically for political expediency, but usually they are relatively constant.

Future growth in each ward depends on many things; for example, topography and geology, rail facilities, zoning ordinances, etc. Much data on trend of development can also be obtained from Boards of Trade, Investment Bankers, Retail Trade Associations, etc. The automobile has made possible the development of outlying districts heretofore relatively inaccessible, and it would seem that the general movement of population has passed the highly centralized stage and is expanding toward the suburbs. Probably 25 years is as far ahead as it is safe to try to predict. Even this short period is hazardous in New England and the Maritime Provinces, where population seems to be definitely decreasing.

For each ward, then, a forecast of probable growth in population can be made. Next comes the probable demand for water. Per capita consumption varies greatly with the quality of the water, class of consumers, type of consumers and pressure. In general, per capitas are on the increase. Mr. Carpenter of Pawtucket has made interesting studies on the actual use of water in tenement districts, and finds rates extending from 12 to 20 gal. per capita, for this class of consumer. These are actual meter readings and include the house waste.

For ordinary dwellings, the actual consumption may be taken at 30 gals. per capita and 50 gals. for the higher class. These may be doubled to care for ordinary waste and 5 gals. per capita added for public uses, such as fires, fountains, street-sprinklings, etc. This gives the probable domestic demand for water. Industrial demand is always problematical and can only be estimated. The fire demands are definitely prescribed by the underwriters. Assuming the maximum domestic and industrial demand to be 50 per cent. greater than the average and to coincide in time with a major conflagration, the maximum probable demand for water in the ward at any time is obtained. It is also very helpful to isolate a ward and measure directly with Pitometers its present water consumption.

Our attention is next turned to the existing facilities. In our work we first measure the normal flow in each trunk and then determine its coefficient of friction, that is the value of "c" in the Chezy formula. In a few instances this may be done with a U-tube and long lines of connecting hose. A better method is to measure the loss of head directly in as long a stretch as possible. Frequently we make a measurement on 10 000 ft. of main, thereby including the valves, branches, and bends which have some slight effect on the total loss. The method is essentially as follows:

The section of main to be tested is isolated by closing off the side connections, thus insuring the same flow throughout the entire section. The main is then tapped at both ends with standard 1-in. corporation cocks, and simultaneous Pitometer measurements made of the flow into and out of the section. Any discrepancy between these two measurements indicates

either leakage or an open connection between the two Pitometers, and this must be remedied before further work can be done. The flow being substantially the same at both ends of the main, recording pressure gages are attached and simultaneous records of both flow and pressure are made for a period of half an hour or more. The gages used were developed especially for this work. They have circular charts revolved by clockwork once in every four hours. They are made to record three ranges of pressure: from 0 to 150 ft. of head; from 150 to 300 ft.; and from 300 to 450 ft. of head. They are calibrated so that a pressure increase of 10 ft. head will produce a pen movement of one-third of an inch on any gage. The ruling of the chart is such that the pressure may be read directly to one-half ft. of water, and by comparing the charts made at the two ends of the main and selecting ten or more peaks and valleys from the record, an average loss of head is obtained accurate to 0.1 ft. Usually a needle valve must be used on each instrument to eliminate surges. The loss indicated by the two gages must be corrected by the difference in elevation of the two stations, and from this true loss of head, the length of main, and mean velocity, the coefficient of friction may be calculated. These coefficients vary widely with the quality of the water. In Springfield, Ohio, with hard water, values of "c" of 120 are found for mains 20 to 40 years old; while in Baltimore, Md., with soft water, mains of the same age showed values of 70 or even less. Coefficients as low as 44 were noted here.

Thus we obtain information as to the local pipe characteristics, and can forecast the probable coefficients during the next 25-year period.

Having then the information regarding population, per capita consumption, maximum flow, and pipe coefficients, it only remains to determine what size mains will be needed to handle the maximum demand, and where to put them. By inspection of existing maps, the weakest spot in the ward is selected and the maximum flow assumed for that point. By using the Freeman Graphical Analysis, the resulting pressure is readily computed, and if deficient, the necessary pipe sizes are determined. Enough other points are chosen to insure ample supply for the entire area. The location of new trunk mains will necessarily depend upon local geology, condition of pavements, location of large consumers, projected highways and improvements, etc. The grid system usually takes care of itself; a minimum of 6-in. in residential districts and 8-in. in thickly settled sections is advisable, but the location and size of the trunk main is important.

It next becomes necessary to be sure that each ward will receive the maximum without injury to the pressure in other parts of the city. Here again the Freeman Graphical Method is of great help and indicates where reinforcements or new loops will be needed. In cities it is customary to assume two major conflagrations occurring at one time, and design accordingly.

Once these new mains are decided upon, they may all be put on one sheet and their relative importance determined, together with relative cost.

A schedule is then drawn up, preferably in 5-yr. periods, and a definite amount of work assigned to each period. This schedule is a guide, and not a rigid rule. It may be advanced or retarded to meet conditions. In this the price of pipe and labor, and the surplus available are the controlling factors. The principal idea is to have a definite program in mind, and work to it. It should be an item in the annual budget as essential as "pay rolls" and adhered to as strictly as "meter repairs." Like life insurance, it may seem like burying money, but in the long run will repay itself many times over.

DISCUSSION.

EDGAR K. WILSON.* I wonder if I can visualize for you a little better the situation at Toledo, Ohio. In the southwest part of the city there is a main pumping station. From the main pumping station, extending towards the northeast, there is a 36-in. main running directly to the center of the city. Running almost directly north from the pumping station is a 30-in. loop which runs for approximately three to three and one-half miles and loops around to the center of the city, where it connects with the 36-in. In the northwest portion of this loop, just separated by a short distance from the main 30-in. line, is the big plant of the Willys-Overland Automobile Company. The fire flow-test at this point shows a very low flow, and for that reason this new 30-in. main which Mr. Hough mentioned, was designed running north from a 42-in. main from the pumping station which would be laid approximately to the center of the city somewhat nearly paralleling the 36-in.

The new plant of the Toledo Water Works will be located in the northeast corner of the city and there will be a low pressure tunnel running approximately through the business center to the old plant. The present plan is to lay a 48-in. pipe in this low pressure tunnel running to the center of the city, connecting both to the present 36-in. and the 30-in. pipes and boosting the pressure at that point. When the entire new plant is in operation this 48-in. pipe will be taken out of the tunnel and used in other parts of the city where it is needed. The flow to the Willys-Overland plant will then be taken care of to some extent from the northeast. The tests showed that by forcing the present 30-in. to feed properly in this manner, the proposed 30-in. main was not needed.

In Baltimore, Mr. Seims has, in the past, run quite a number of different types of tests. His waste survey has been very successful and tests have been made of fire flows, electrolysis, and valves; two years ago a complete trunk main survey was made to which Mr. Hough has referred. We found some very peculiar conditions there which were taken up quite thoroughly in a paper by Mr. Seims and the speaker before the American Water Works at the convention last June, which has just been published.

* Chief Engineer, Pitometer Company, New York City.

In Philadelphia the flow from the pumping station comes down in three 60-in. mains, two of which are used for low pressure and one for high pressure. It has been found there that the center of the city was not adequately served, and they are planning to lay several miles of express mains, as they call them, to carry the water from the pumping station. As the result of measurements of the three present 60-in. mains it was found that by putting one 72-in. main at some distance to the east they could change over the 60-in., now used as high pressure, and the two 60-in. mains and the 72-in. would then give the same results at about half the cost of the previously proposed work.

In a small town in the western part of New York where some tests were made last year we found that their supply by gravity from springs would not now fill their reservoir at any time, and has not been filling it for several years. Recommendations were made as the result of flow tests on the supply lines from the springs, which resulted in rebuilding the supply lines to one section of their spring area; and a recent letter from them showing the results approximated those expected within a small percentage.

It may be interesting to know how the coefficients found in this work compare with Williams and Hazen's tables; and I might say that in most cases where the pipe is new we find that we are within two or three points of their coefficient for new pipe. That would be easily taken care of, I think, in the bends, specials and valves in a long line of pipe. When the pipe gets somewhat older it depends entirely on the character of the water. As Mr. Hough said, in Springfield, Ohio, where the water is very hard, the pipe coefficients were very high. There was one 24-in. pipe from the pumping station which was 44 years old and in which the coefficient was 116. The other tests that were made also showed very high coefficients.

On the other hand, many instances have been found where the coefficients are much lower than the tables would indicate for the age of the pipe.

CHARLES W. SHERMAN.* It is becoming increasingly common for water systems to undertake the kind of surveys which Mr. Hough has described, and to make plans for systematic improvement and extension of their plants. The firm of which I am a member has had occasion to make a number of such examinations and recommendations. Most commonly they are not undertaken until the system has become inadequate to such an extent that some radical steps must be taken. Consequently, the method suggested by Mr. Hough of setting aside a portion of the earnings each year and doing something on the required extensions is hardly sufficient at the time. The first step in such conditions usually must be an appropriation of considerable magnitude and a rather radical reinforcement of the system. Comparatively few water systems have recognized the desirability of such steps until they were forced to it by occurrences of that kind.

* Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

I think invariably — at least in every case of which I have knowledge — the study and report indicated what should be undertaken at once, together with a program of further extensions to be made from time to time, within a reasonable period of years, along the lines suggested by Mr. Hough. Whether or not these were to be done by setting aside and utilizing a portion of the annual water revenue, or whether they were to be financed by other methods, naturally was not the province of the water survey report to cover. Unfortunately in too many of our municipal plants the water revenue goes into the city treasury and can only be taken out by a vote of the City Council, in which case, whatever the desires of the water officials to make extensions year by year, they are dependent upon favorable action by the City Council. So that it is not nearly so difficult with a reasonable plan of annual improvements and extensions to get appropriations for steps towards that, as it is to get the larger appropriations required for major reinforcements.

Mr. Hough did not mention, although it has been referred to here, the valuable aid that is so frequently obtained from the flow tests made by the insurance inspectors. They do not show nearly as much information as the pitometer test and do not allow such detailed study, but they do show up very satisfactorily the inadequacy of the supply at vital points in the system when information is desired, and furnish a most valuable argument for reinforcement when needed.

We have had occasion to make some studies where the more elaborate tests were not justified, or were not possible of attainment, and where we have been able to work out the results with a reasonable degree of satisfaction on the basis of the flow tests, sometimes supplemented by approximate tests of the carrying coefficient of pipes, by the use of ordinary pressure gages, and assumptions as to the actual quantity flowing based in part on the flow tests at hydrants. We were privileged during the past year to actually undertake the reinforcement work for one of our Massachusetts cities, taken up as the result of our recommendations, and this involved the removal and replacement of quite a bit of old pipe as well as the reinforcement of other sections. It was interesting to note one case of a six-inch dead-end pipe, which was more than half filled with tuberculation and accretions, and in which the carrying coefficient certainly must have been as low as 30. There was no opportunity to make a test, but we did get a photograph of the pipe as an exhibit, and people who saw it were certainly interested.

The program of making extensions in such a way as to ultimately form parts of a well-planned system sometimes results in temporary periods of very peculiar looking pipe systems. For instance, you might find a section of 1 000 or 2 000 ft. of 12-in. pipe on a line consisting of six-inch pipe at either end — fed and drained by six-inch pipe. It is not justified for the moment, but it does provide an important step, perhaps all that can be afforded at the time, towards an ultimate larger sized pipe which will provide adequate service.

Certainly a plan to work to is the greatest advantage to any water department.

HENRY A. SYMONDS.* One point which has been brought out or suggested in this very interesting paper seems to be well worth giving more consideration to than has been given in a great many cases. That is, determining accurately the condition of the water-works system before improvements are carried out.

I have in mind four cases that have occurred within the last few years where extensive additions apparently were necessary in order to give adequate fire protection. Two of these were found entirely unnecessary by a careful study of the system, which located large leaks, so that when those leaks were taken care of, it entirely changed the situation and large amounts of money were saved.

Now regarding two other cases which perhaps are more common. In a Massachusetts town a large fire occurred, burning most of the houses in a good-sized block. The hydrant service had proved very weak, and it was immediately assumed that the mains were too small. Provision was made to lay a new system of mains through that section. Investigation with pitometer tubes showed very surprising results. The good pressure was maintained with the flow of a single stream, but when we should have had about four streams, theoretically there was no service at all. It was suggested that there must be some obstruction in this main, possibly a gate closed, although the superintendent was very sure that such a thing was not possible. An investigation showed that one of the gates on the main line to the reservoir was nearly closed, and that was the reason that the fire got such headway.

More recently we have had a case where it was proposed to put in a new pumping plant, but found a surprising discrepancy between theoretical and actual pressures as shown when the temporary pump was in operation. Investigation proved that a gate had been closed at the time of a break in mains, a year or two before, and that the foreman had forgotten to open it except a very small amount. The pump had been working many months against a very light head due to the condition of the gate. Failure to discover the trouble would have caused installation of unnecessarily large engines.

These and other instances somewhat similar, have emphasized the importance of all water departments, making very careful and frequent inspections of the condition of their gates, as it is probable that there are a great many gates closed, not perhaps often on the main lines — although these two I speak of were on main lines — but on the distribution system and affecting the fire service or the pumping pressure. It is one of the things that is up to all of us who have to do with managing water works.

* Consulting Engineer, Boston, Mass.

THE TYPHOID FEVER EPIDEMIC OF 1885 AT PLYMOUTH, PENNSYLVANIA.*

BY CHARLES W. SHERMAN.†

This epidemic of typhoid fever is of interest to water-works men, as the first in America which was definitely traced to a polluted water supply. Even then, comparatively few people accepted the "germ theory" of disease, and many refused to believe that the connection existed, although in the light of present knowledge it is easy to see exactly what happened.

The following account is based upon the story told to the writer, in 1917, by Oscar M. Lance, who was superintendent of the Plymouth Water Co. at the time of the epidemic.

The water company was formed in 1875, and developed a supply of water from Coal Creek, a small stream with drainage area at the point of taking of only about 0.8 sq. mile. Figure 1 is a sketch map of the stream and reservoirs.‡ The two lower Reservoirs, Nos. 1 and 2, were of slight consequence except as points of diversion. Reservoir No. 3 has a capacity of about 3 million gal. with a depth of 25 ft., and a surface area of about 0.8 acre; Reservoir No. 4 contains about 6 million gal. at a depth of 10.7 ft., and covers about 1.7 acres. Coal Creek flows into Susquehanna River about a mile below Reservoir No. 1, and there was a pumping station on the bank of the river above Coal Creek and about 10 000 ft. from Reservoir No. 1, for use in case the Coal Creek supply were exhausted.

There were but two houses on the drainage area, located as shown on the map. In one of these, the John Davis house, there was a boarder, one David H. Jones, who came from Philadelphia in the winter, suffering from a "severe cold," and was confined to the house for some time; after a while his illness was found to be typhoid fever. His dejecta were thrown out on the snow behind the house, on a steep slope and but a short distance from the bank of the creek.

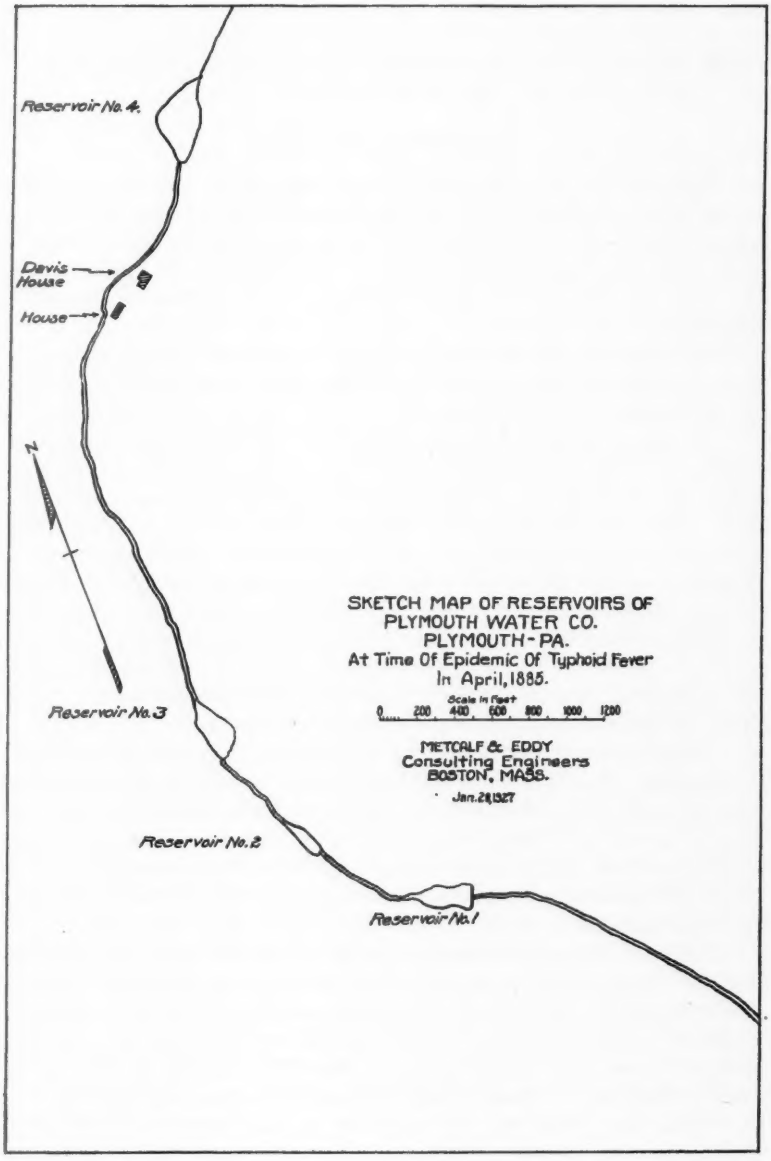
Early in February the reservoirs were all full; but very cold weather followed, many faucets were left open to avoid frozen pipes, and in a few weeks the supply was entirely exhausted. On March 20, the emergency pump was started, drafting Susquehanna River water; but this was unpleasant to use, and many complaints resulted. On March 26, a warm rain occurred, the reservoirs rapidly filled, and the pump was stopped.

While the pumps were in operation, a small amount of water had accumulated in Reservoir No. 3, but the outlet pipe had frozen solid.

* See also Sedgwick's "Principles of Sanitary Science and the Public Health," page 200.

†Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

‡ Copied from the Water Company's map.


Reservoir No. 4.
Davis House
House
N
Reservoir No. 3
Reservoir No. 2
Reservoir No. 1
SKETCH MAP OF RESERVOIRS OF
PLYMOUTH WATER CO.
PLYMOUTH - PA.
At Time Of Epidemic Of Typhoid Fever
In April, 1885.
Scale in Feet
0 200 400 600 800 1000 1200
METCALF & EDDY
Consulting Engineers
BOSTON, MASS.
Jan. 28, 1927

Discovering this, and anticipating a thaw, Mr. Lance thawed out the pipe so that the water of the first runoff following the thaw was drawn directly into the distribution pipes. As noted above, this was on March 26. The presence of an epidemic was detected about April 10, and in the panic which followed a great many people left the town.

Statistics show that recognized cases of typhoid occurred as follows:

April	713
May	261
June	83
July	31
August	15
September	1

1 104 of which 605 were males and 499 females.

Of the 1 104 cases, 114 resulted in death. In view of the large exodus from town, it was estimated that there were about 1 150 cases and 120 deaths.

A significant summary of the conditions, — quoted from the "Paper Book of Appellee" (or defendant's brief) in the case of *William Buckingham* v. *The Plymouth Water Co.*, — Supreme Court of Pennsylvania, Eastern District, — No. 386, January term 1890 — is as follows:

"About the middle of April, 1885, several persons in the borough of Plymouth became sick with a fever. The disease spread until some 1 200 were affected. The local physicians attributed the disease to the bad sanitary conditions of the town. There was no sewage system, all manner of filth had been freely strewn on the surface of the ground in the town and around the houses during the winter, and when the warm weather of spring appeared there were conditions well calculated to engender disease. The nature of the sickness was believed by the physicians to be malarial and steps were taken by the authorities to clean and disinfect the borough. The magnitude of the outbreak attracted public attention, and in pursuance of an invitation by the Mayor of Philadelphia, Dr. Shakespeare and the Chief Police Surgeon of Philadelphia, Dr. French, visited Plymouth to investigate the causes that produced the disorder and to ascertain if help, which had been solicited, was needed. These two gentlemen made an investigation of the town and its surroundings, and also conducted post mortem examinations of some of those who had died. The conclusion reached for the first time was that the disease was typhoid fever and that it had its origin in the water supply of the borough. That the water had been contaminated by the dejecta of a fever patient who had been ill with typhoid fever at a house situated on the bank of Coal Street Creek, which was the main source of the water company's supply. The case had occurred in January, the house was two miles or more from the town, on the mountain side in an isolated situation. It was learned that on two or three occasions during the inclement weather the nurse of this patient had thrown discharges from his bowels on the snow at the rear of the house instead of into the privy vault, as instructed by the attending physician. The theory adopted by the doctors was that two or three months afterwards, when the snow melted, the dejecta was drained into the stream and through the four

reservoirs of the Water Company and finally into their pipes and that it produced typhoid fever. These facts were substantially proved and these theories adduced by the plaintiffs' witnesses. With the exception of four or five days, from March 20 to 26, when the water was pumped from the river the town was supplied from Coal Street Creek. During those days the water in the creek was frozen and no supply could be obtained from that source. For some reason, known only to counsel, an attempt was made to introduce testimony to prove that two small streams, running into the Susquehanna River, called Toby's Creek and Whitewash Creek, were contaminated by sewage, and that during the winter of 1884–85 cases of typhoid fever had occurred along their banks, and that privy vaults drained into these streams. One of them empties into the river at least a mile and three quarters above the intake of the Water Company, and the other 2 800 feet above. They come in on the west side of the river, whereas the intake is several hundred feet from the bank towards the eastern shore, and extends beyond the reach of any contamination from the creeks.

"The offer of the plaintiff was to prove the condition of these streams, and to affect the Company with constructive notice from public repute. It was rejected by the Court on the ground that the Company could not be affected with constructive notice in that way.

"The Court allowed the plaintiff every opportunity to prove actual notice to the Company of the unfitness of their water for public use, but his efforts in that direction failed. On the contrary he showed that the water furnished the people was considered about the best in the State.

"Up to the time when the investigations and post mortems were held no one had suspected the water as being the cause of the sickness. Even now it is only a theory held by some physicians and disputed by others.

"The public knowledge at the time the sickness commenced on the subject of the transmission of typhoid germs and their multiplication in water was very limited. It was in fact only a theory, strongly advocated by some experts and denied by others. Probably no member of the Plymouth Water Company ever heard of a typhoid germ, or of the germ theory, or ever dreamed that the disease could be transmitted through millions of gallons of water from a lonely house on the mountain side to people in Plymouth. They do not know it now except as a theory to which some facts point."

THE POISONOUS EFFECTS OF COPPER.

BY F. B. MALLORY, M.D.*

[*Read February 9, 1927.*]

It is my function at this meeting to call your attention to the dangerous effects of small quantities of copper taken into the body over a long period of time. My paper is to serve as an introduction to the second which treats of a subject of the greatest importance to you all, namely; is there any danger in the use of copper pipes, tanks, and heating coils in connection with water employed for drinking purposes?

For nearly 30 years I have been interested in the subject of cirrhosis of the liver. That is a chronic disease, due to injury of the organ, which results in destruction of liver cells and in increase of the supporting connective tissue which holds the organ together. As a result of this chronic inflammatory process, sometimes called chronic hepatitis, the organ is increased in density and in time, if the patient lives long enough, is diminished in size. Several different types of the lesion, or change in the organ, are demonstrable. The commonest is sometimes called alcoholic cirrhosis, because so often found in heavy drinkers. It is characterized microscopically by a striking degenerative change in the liver cells. For many years I have sought by experimental methods for the particular chemical substance which causes this peculiar lesion or cell change. It is very generally agreed that ethyl alcohol itself does not do it. It must, therefore, be some contaminating substance occurring in liquors. While testing out the effects of various metals my attention was called to the injurious effects of copper on the liver. It took a long time to discover how the damage was produced but in the end the process was found to be comparatively simple. I shall present the results as clearly and directly as possible without tiring you with the details of the round-about methods by which I first obtained them.

Copper taken into the body in any form is easily absorbed. Getting into the circulation it has the property of causing hemolysis, that is, of setting free from the red blood corpuscles the coloring matter, hemoglobin, which is in them. Hemoglobin in small quantities is readily eliminated through the kidneys. If too much, however, is set free in the circulation, a certain amount of it is deposited in the liver in a changed form as a light yellow pigment called hemofuscin. This pigment, like the hemoglobin from which it is derived, contains iron, but so intimately combined with protein material that it will not give the reactions for that metal. On the other hand while hemoglobin stains intensely with acid aniline dyes such as eosin, hemofuscin stains deeply with basic aniline dyes such as methylene

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blue and fuchsin and therefore can easily be recognized. In the course of time, months to years, hemofuscin undergoes under the action of cells a chemical change into hemosiderin, an orange yellow pigment which does not stain with acid or basic aniline dyes but does give the reactions for iron.

The next step is to trace the injurious effect on the liver of the pigments derived from hemoglobin. If the hemofuscin accumulates rapidly in the cells it may kill off many of them in the course of a few weeks; if slowly, many months may be required. In the course of time the hemofuscin is very gradually changed to hemosiderin. Cirrhosis can be produced in a few months if the dose of copper is large enough. Then the only pigment present is hemofuscin. If too much is given the hemoglobin blocks up the tubules of the kidney, causing hemoglobinuria and death. If the dose is small the animal lives for years. In one rabbit at the end of four years the liver was of a dark chocolate color, owing to the presence chiefly of hemofuscin, and the surface was granular with small white to gray nodules in places. The latter were groups of regenerated non-pigmented liver cells. Owing to the contraction of the increased connective tissue the rabbits usually develop marked jaundice before death. Small amounts of pigment were found in the pancreas and heart of the animals which had lived longest.

To sum up: copper injures the red blood corpuscles and causes hemolysis. The homoglobin set free in this way is deposited as hemofuscin in the cells of the liver. Later it may break down into hemosiderin. The deposit of pigment injures the liver cells and in time kills them. Regeneration and increase of connective tissue take place resulting in cirrhosis of the liver.

The cell changes produced in the liver of animals by the injurious action of copper suggested that the lesions (i.e. cell changes) of a chronic disease known as hemochromatosis might be brought about in the same way. Therefore, a very thorough study was made of the organs from all the cases obtainable, some twenty in number. Hemochromatosis has long attracted attention both clinically and pathologically owing to its striking and characteristic features which are pigment cirrhosis of the liver, sclerosis of the pancreas with diabetes mellitus, and bronzing of the skin, especially over the extremities. If the lesion is limited chiefly to the liver, we speak of pigment cirrhosis. If the diabetes and the skin pigmentation are prominent the French have been accustomed to call the condition bronzed diabetes. But the lesions and symptoms are all manifestation of one very chronic diseased process.

von Recklinghausen long ago called attention to the fact that two pigments were present in the liver and other organs of this disease. One pigment gives the iron reaction; the other does not. The application of improved staining methods showed that the pigment in the old liver cells was hemosiderin but that that in the recently regenerated cells was hemofuscin, the same pigment found in the animals killed by the action of copper. Its gradual transformation to hemosiderin could be followed in islands of regenerated cells which were somewhat older. While certain cells trans-

form hemofuscin quite readily to hemosiderin others cannot do so. As a result hemofuscin can often be found in large quantities in the smooth muscle cells of blood vessels, in the wall of the stomach and elsewhere.

Hemochromatosis requires many years for its production, 15 to 30 or more. It has not yet been possible to carry the chronic poisoning of animals beyond four years, consequently all the changes found in man have not yet been duplicated but so far as they have been carried the lesions in animals and human beings agree in every way.

If hemochromatosis is due to chronic poisoning with copper it is natural to inquire into the ways through which the metal is introduced into the body. Clinicians have long noted that many of the patients afflicted with this disease have been heavy drinkers. Chemical examination of liquors of various sorts have shown that copper is very commonly present in those which have been distilled. I was able to interest Mr. Hermann C. Lythgoe, Director of the Division of Foods and Drugs of the Department of Public Health of Massachusetts, in the subject and he has had carried out a series of nearly 2 000 examinations on liquors. Copper has been found in a little over 10 per cent. of them in amounts running from a trace up to 69 mg. to the liter. One specimen in a small series examined for me by Dr. Lawrence T. Fairhall of the Harvard Medical School contained 185 mg. of copper to the liter. A little calculation shows that if a man were to drink a quart a day of this particular liquor he would take into his system about 1 gm. of copper a week, 52 gm. a year or a pound of metallic copper in less than 10 years.

The presence of the copper in liquors is due to the action of organic acids. They are distilled over from the mash along with the alcohol and readily act on the copper worm of the condensor.

Another source of copper poisoning was found to be occupations in which men had come into intimate contact with copper dust for many years. One of the best examples I have was that of a man who had "worked in a shop, milling and turning copper and brass" for 14 years. Another had worked for many years in the orthopedic department of one of our hospitals, making apparatus for patients. At first no source of poisoning was evident but eventually it was found that in joining his metal pieces together he had used a solder containing copper and then had filed and polished the surface to make it smooth. In this way he had been exposed for years to the inhalation of copper dust. Experiments on rabbits showed that finely powered metallic copper taken into the body through the lungs or stomach is readily dissolved.

Careful investigation of the series of cases of hemochromatosis which we have had at the Boston City Hospital during the past 30 years (now over 20 in number) has shown that liquor and occupation would explain the source of copper poisoning in about two-thirds, perhaps more, of them. To find any definite source in the remaining third has been difficult and no conclusive results have so far been obtained. Two possible sources are

open to suspicion, foods and drinkables which have been cooked or stored in copper vessels. Pickles, peas and beans are no longer cooked and colored in copper kettles as in the past: at least the sale of such vegetables is forbidden by law. But in the country apple butter is regularly made by cooking apples slowly in cider in a copper kettle for one to two days. Experimental testing shows that the malic acid in cider readily attacks copper.

One thing seems certain: copper vessels should not be used for cooking foods or fruits because it is easy to demonstrate that the metal is readily attacked not only by acetic and malic, but also by citric, lactic, oleic and various other organic acids.

We come finally to the question of the use of copper in the form of pipes, tanks and coils for the conveyance, storage and heating of water used for drinking purposes. This is a line of work entirely out of my field, because I am not a chemist. So far I have taken the ground that there is no evidence against this use, although the brass pipes in Brookline and some other cities are badly eroded after 15 to 20 years' usage. It is claimed, I believe, that it is the zinc which is dissolved out. I have had many letters from different parts of the country seeking information on this subject and hope that the next speaker will be able to answer some of them.

As a sample, here are the questions asked by the "World's Foremost Heater Builders."

1. What effect is there on drinking water from storing in an unlined copper boiler?

2. What effect from storing in an unlined copper boiler with soldered seams?

3. What effect is there from storing in a copper boiler lined with tin?

4. What effect from storing in a copper boiler with brass head and bottom? (Brass composed of 85 per cent. copper, 5 per cent. tin, 5 per cent. lead and 5 per cent. zinc.)

5. What is the effect in all of the above cases where the temperature range is from 35° F. to 180°?

Chemical examination of the liver and other organs from patients dying of various diseases shows that copper is often present in small amounts. This indicates two things, first that we are constantly exposed to copper and second that we can handle a certain amount of it without danger. How much, it is difficult to say — perhaps 5 to 10 mg. a day; it may be less or more.

Possibly susceptibility plays some part in the development of the pigment deposit in the liver and other organs to which we apply the term hemochromatosis. Rabbits are moderately susceptible to poisoning by copper, sheep exceedingly so, while guinea-pigs are only slightly so, or not at all. In like manner some people may be injured by very small amounts of copper which would not affect other people in the slightest. On this account exposure to copper in any way should be reduced to the minimum.

THE EFFECT OF PIPES OF DIFFERENT METALS UPON THE QUALITY OF WATER SUPPLIES.

BY H. W. CLARK.*

[*Read February 9, 1927.*]

During the past few years a great many studies concerning corrosion have been made and papers published in regard to different phases of the subject. These papers have largely elaborated facts concerning corrosion from the point of view of the weakening or destruction of iron or steel pipes and other metal structures and many statistics have been given to show the great loss of iron and steel stated in hundreds of thousands of tons per year by such corrosion. In these papers the effect of temperature, of pressure, of velocity of flow and other contributory factors have been discussed and elaborated. Two years ago Mr. Speller, metallurgical engineer of the National Tube Company, talked to you upon the subject of iron and steel corrosion under water and of methods for its prevention. Mr. Robert Spurr Weston in 1920, read a paper to this Association upon lead poisoning by water and its prevention largely by adding carbonates to cause protective coatings on the pipe. In 1910 and later, the effect of high temperatures upon corrosion was studied by the speaker and his assistants and notes in regard to it were published in the report of the Massachusetts Department of Public Health, and in the last number of the *Journal of Industrial and Engineering Chemistry* are articles by Russell, Chappell and White on "The Effect of Velocity of Flow on Corrosion of Steel under Water."

I am not intending in this paper to enter into the history of corrosion or the destruction of metals by it; or the history of lead poisoning from lead pipes; but wish to call attention to an article published in 1910, by the speaker and one of his then assistants, Mr. Stephen DeM. Gage, at the end of which references were given to 68 papers on this subject appearing between 1871 and 1910 in American, English, French and German technical journals. Probably since 1910 as many more have been published on this interesting topic.

In connection with these recent corrosion studies certain apparatus has been described to deactivate water; that is, to take from it its dissolved oxygen in order that it may be less corrosive, and suggestions have been made in regard to the addition of sodium silicate or other chemicals to water in order that this chemical might coat the interior of pipes and thus prevent corrosion. On a small scale, that is, with the average water supply of an industrial plant, both of these methods are practicable up to a certain point. On a municipal water-works scale, however, the first appears to be of no appreciable value but the second or silicate method is said to be used success-

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fully with certain municipal supplies abroad. This destruction of iron and steel pipes and other water-works apparatus or fittings is probably the phase of corrosion in which most of the members of this Association are chiefly interested but we are also interested in the other phases — the first being concerned with what the water does to the pipes, and the second with what the pipes do to the water — and it is in regard to this second phase of the subject I am intending to mainly talk.

Theories in regard to the action of water in causing corrosion are, at the present time, stated in various ways but express the same idea. The iron and steel chemists state that where water is confined in closed systems of iron or steel the free dissolved oxygen of the water is either the probable cause or the probable contributory factor causing corrosion. The removal of oxygen will in most cases practically stop corrosion and in other cases materially reduce corrosion by any other agency. Free carbonic acid they state promotes corrosion in the presence of free oxygen but is practically negative in the absence of this oxygen except at high temperatures. Carbonates of calcium and magnesium and other temporary alkaline salts, that is, those that cause temporary hardness of the water, retard corrosion by being deposited in the form of a protective coating on the metal, but at high temperatures these carbonates may give off carbonic acid or caustic solution, thus permitting corrosion to take place. Carbonic acid in considerable amounts prevents the formation of this coating and the pipe is kept clean by this carbonic acid, giving a chance for the oxygen to dissolve metal continuously.

As nearly as we could find when studying this subject in 1910, the carbonic acid theory of corrosion was first outlined in 1871 but not until 1888 was it seriously discussed.

Now going back a little farther than the 1910 paper I wish to call attention to two papers published by the speaker in 1898 and 1900. The studies of corrosion described in these two papers were made about 30 years ago and were begun on account of a number of cases of lead poisoning in certain municipalities using lead service pipes. In the course of the investigation to ascertain the reason of this lead poisoning and the cause for certain waters dissolving lead much research work was carried on both at the municipalities in question and in the laboratories. It was found in the course of this investigation of the municipal water supplies, in connection with research work, that while in laboratory experiments oxygen was the chief factor in dissolving lead, in the conditions prevailing in service pipes a dangerous amount of lead was not generally found in solution in these municipal supplies except that supply contained a generous amount of carbonic acid and was also soft. The soft or comparatively soft ground waters high in carbonic acid but often containing little dissolved oxygen were found to be the most active in this lead-dissolving property while surface waters soft and often saturated with free oxygen but low in carbonic acid had, under the conditions prevailing in service pipes, generally, only slight lead-dissolving power.

In the second of these two articles, that of 1900, describing this investigation I made the following statements: — "The cause of the taking of lead from the service pipes by the water of certain towns and cities was the presence of a considerable volume of free carbonic acid in the ground waters which actively attack lead" and that "while many laboratory experiments have shown that pure soft water, especially when containing dissolved oxygen attacks lead, while the presence of coloring matter, free ammonia, nitrates and nitrites in soft water also causes considerable action upon lead in laboratory experiments, yet taking into consideration the results of our entire investigations we find that in actual practice in the conditions prevailing in the service pipes of a distribution system a potable water in Massachusetts to have any dangerous lead-dissolving action must contain considerable free carbonic acid;" that "water simply soft and comparatively free from mineral matters in solution did not take a dangerous amount of lead in solution from service pipes in actual use, however such water might act in laboratory experiments." It was also stated in that article that there were some indications that the composition of the mineral contents of a ground water might influence slightly its action upon lead and also that any considerable quantity of oxide of iron separating from the water and depositing in the service pipes also had at times an appreciable action.

While the ground waters were those chiefly under indictment at that time as they took the greater amount of lead into solution and cases of lead poisoning were found only in certain municipalities having such supplies, yet the following statement was made concerning the surface supplies:— "Many of these waters attack lead and the lead taken in this manner into the systems of the users may cause mild or unrecognized cases of lead poisoning."

In those early days we did not discuss self-corrosion, as it is now called, or the present theory of solution by the interchange of positive and negative charges of the ions into which the molecule H_2O is now supposed to be dissociated and the taking into solution of ions of the various metals. This was discussed somewhat, however, in the paper upon corrosion by Mr. Gage and the speaker which I have already mentioned as published 16 years ago. At the present time the molecule of water is considered as an active substance with the power of dissociation; that is, pure water contains in addition to the molecule H_2O a number of hydrogen ions and hydroxyl ions, the hydrogen ions being positively charged, the hydroxyl ions negatively, and hence an electric balance or equilibrium results. When a metal is immersed in water it discharges into this water a certain number of minute particles positively charged, that is, metal ions. These positively charged metal ions destroy the electrical equilibrium of the water and positively charged hydrogen ions pass to the metal, lose there their positive charge and form a coating of hydrogen gas over the metal, protecting it from further action unless oxygen is present in the water. If this is so, water is formed by chemical reaction between the hydrogen film and the oxygen. The

metal is again exposed, metal ions go into solution and the process of corrosion continues. This continues as long as there are hydrogen ions to neutralize the metal and enough free oxygen to remove the hydrogen film.

The part of carbonic acid in this modern theory comes in in this way. CO_2 forms a weak acid in water which tends to increase the hydrogen ions of the water. Some of this carbonic acid may be needed to hold in solution carbonates of calcium and magnesium but the remainder is free carbonic acid or in the modern language aggressive acid, owing to the hydrogen ion increase. Hard waters in which the content of bicarbonates is large can contain fairly high amounts of carbon dioxide without any of it becoming aggressive, as it is employed in holding these bicarbonates in solution, but soft waters free or comparatively free from these bicarbonates become aggressive even when containing relatively small quantities of the acid. That in the present chemical language is the explanation of what I stated 30 years ago in much simpler terms, namely, that a water under such conditions as exist in metal service pipes, especially lead pipes, must contain considerable carbonic acid and be comparatively soft if metals are to be taken into solution in any considerable amount. The further explanation of 30 years ago was that owing to the oxygen present in the water in these service pipes a coating of oxides of lead, basic carbonates of lead, etc., was formed on the pipe interiors and that if only small amounts of carbonic acid were present in the water and the ground water was fairly hard this coating was permanent or practically so but if the water was soft or comparatively soft and contained a considerable amount of carbonic acid this coating would be continually dissolving, reformed and dissolved again or in the present language metal ions would continually go into solution, hydrogen films be formed on the metal, the hydrogen film again destroyed by the action of oxygen and continual solution take place, the carbonic acid being a necessary factor in continuing this solution of the metal.

Practically every water takes iron into solution and the greater the amount of dissolved oxygen present the greater the amount taken. Fortunately the iron taken into solution in this way from mains generally affects but slightly the quality of the water. Corrosion and solution of iron and tuberculation at one point are neutralized by deposits of iron in another. Iron pipes fill with iron rust, organic matter and microscopic growths, but little of this iron comes from the faucets except at times of disturbance of the supply by flushing, sudden changes in pressure, etc. Accumulations of iron in dead-ends sometimes disturb the minds of householders at such locations. At first thought it seems peculiar that this is so when water which contains iron, on entering the supply such as an iron-bearing ground water, carries this water through the pipes and to the consumers. Iron from the ground, however, is large in amount relatively speaking to the amount taken into solution by corrosion. Moreover, it is distributed throughout the entire supply passing rather quickly from standpipe or reservoir to the consumer while solution of iron by corrosion is a slow process

and this iron is out of the main stream of water; that is, is against the pipe itself. A few years ago there was much complaint of red water troubles, so called, due to iron taken from the pipes by certain filtered waters. This red water trouble was caused by active corrosion more intense than the normal corrosion due to the ordinary volume of dissolved oxygen present in the water and was the product of the increase of carbonic acid in surface supplies by alum treatment. This trouble has been largely overcome by proper treatment of filter effluents before use.

Certain experiments made from time to time by the speaker have shown that, ordinarily speaking, twice as much iron is taken into solution in a given time from iron pipes when the volume of dissolved oxygen in the water approaches saturation as when this dissolved oxygen is small in amount, and it has also been determined by these experiments that more iron is taken into solution by hot water than by cold when these waters have a certain degree of alkalinity. The effect of varying the alkalinity of such waters was that any increase caused an increase in the solution of iron by cold water but a decrease by hot water. Pipes tested by standing full for three days showed increases in the iron content of the water varying from 53 to 705 times that normally present, that is, present in the water used. Farther along in this paper I shall speak of the taking of zinc into solution from galvanized iron pipes. This zinc lining, however, of iron pipes is, as of course you all know, of great usefulness in preventing the absorption of iron. Duplicate experiments of those I have just spoken of showed that with the same seven waters placed in galvanized iron pipes for the same period of time, namely three days, the increase in iron varied only from two to eighty-one times that in the water as used. Of course these were new experimental pipes.

During all of the years since the publication of the paper in 1900 entitled, "Action of Water upon Metallic or Metal-lined Service Pipes," studies have been made on the effect of various waters upon lead pipes used as service pipes and in household plumbing. In these studies determinations have always been made of carbonic acid, hardness, dissolved oxygen and, of late years, of the hydrogen ion concentration. Samples from some of these waters in connection with this work, have been few in number but considering the results from 40 to 50 of the ground water supplies of the state examined many times we find that the figures of carbonic acid, dissolved oxygen, hardness, and lead in solution are about as follows, these figures being averages —

In the corrosive ground waters:

	(Parts in 100 000.)
Carbonic acid	2.93
Hardness	3.4
Lead, running sample	0.065
Lead, standing sample	0.170
Dissolved oxygen	48 per cent. of saturation

The running samples were taken when the water was in ordinary daily use

and the standing samples, so called, were collected of water which had stood in the pipe a number of hours.

In the ground waters not corrosive, or at least not dangerously so, the figures are as follows :

	(Parts in 100 000.)
Carbonic acid	1.33
Hardness	3.0
Lead, running sample	0.015
Lead, standing sample	0.040
Dissolved oxygen	44 per cent. of saturation

In the many surface waters examined in the early period of corrosion studies the figures averaged about as follows:

	(Parts in 100 000.)
Carbonic acid	0.45
Hardness	1.5
Lead, running sample	0.009
Lead, standing sample	0.026
Dissolved oxygen	85 per cent. of saturation

Notwithstanding the fact that these surface waters contained twice the amount of dissolved oxygen found generally in the ground waters, these waters were not corrosive in the sense of taking a dangerous amount of lead into solution, or, in other words, permanent coatings were formed in the service pipes of water supplies in which there was not enough aggressive carbonic acid present to prevent or remove this coating. In other words, solution of metal ions did not take place except for a limited period. It must be stated in this connection, however, that occasionally where new and long lengths of lead pipe were installed there were periods at the beginning of the use of water through such pipes, before the formation of the coating, during which dangerous amounts of lead were taken in solution and cases of lead poisoning occurred among the users of these soft surface waters. These results and those following of the Metropolitan supply are from service pipes in actual use.

During the past few years about 70 samples of the Metropolitan supply, the surface water which is most widely used in the state, supplying a population of about 1 500 000 people,* have been examined for lead, these samples all being taken where there was a considerable length of lead service pipes and in the various cities and towns of the Metropolitan district. Averaging these figures we have results about as follows: — Lead in running sample, .0131 part in 100 000; in standing sample, .0190, the maximum results being .0343 and .0629 part, respectively. The dissolved oxygen in the Metropolitan supply averages about 95 per cent. of saturation and the CO_2 about 0.3 part in 100 000. These figures of the Metropolitan supply can be applied quite generally to other surface waters of the state although here and there is a surface water more corrosive than the Metropolitan supply, owing, generally speaking, to the entrance into this supply of larger

*Population of area within 15 miles of Boston including the District, 1 897 437.

volumes of ground water in comparison with the true surface water. This is especially true of certain ponds in sandy territory as a large part of the entering water passes through the ground.

In the early work many investigations were made concerning the corrosion of zinc, tin, brass and galvanized iron pipes and it was found that while tin and the copper in the brass were but slightly attacked yet from both the galvanized iron and the brass pipes large amounts of zinc were taken into solution, at times nearly two parts in 100 000 being found, and it was shown that while as far as the zinc was concerned, ground waters had a somewhat more corrosive action than surface waters but little, if any, more tin or copper was taken into solution by the ground than by the surface waters. The maximum amount of copper found at that time in any ground water supply coming through brass pipes was .0286 and the maximum amount in surface waters through such pipes, .0470 part in 100 000, the average amounts found being much lower than this. These were from pipes in actual household use.

During 1920 some special work was done upon twenty-three ground water supplies of the state largely because of troubles experienced in some of the cities and towns supplied with these waters by the destruction, apparently by the water, of certain parts of iron, copper and brass pipe and fittings. As a result of this investigation it was found that little trouble was experienced in the corrosion of these metals by waters having less than 1.7 parts in 100 000 of carbonic acid but in waters having a greater amount than this, corrosion did occur, some of these waters having nearly four parts carbonic acid. At this time experiments were again begun in regard to the corrosive action of waters upon iron, brass, galvanized iron and copper pipes. In the first work at this time the experimental pipes were filled with one of the most corrosive waters of the state and seven days allowed for action before the water was withdrawn and analyzed. These experiments gave average results as follows:

	Pipe.	Iron.	Copper. (Parts in 100 000.)	Zinc.
No. 1.	Iron	3.0000	....	....
No. 2.	Brass	....	.0720	.1000
No. 3.	Copper	....	.4120	....
No. 7.	Iron and brass	3.0000	.0520	.1480
No. 8.	Iron and copper	2.0000	.0960	.1000
No. 9.	Brass and galvanized iron	0.1400	.0400	.1120

The water used contained 3.7 parts of carbonic acid and the dissolved oxygen was 27 per cent. of saturation.

Further experiments upon the brass and copper pipes with both hot and cold water with contacts of one week gave the following average results:

		Copper. (Parts in 100 000.)
Brass pipe:	Hot water	.0500
	Cold water	.0850
Copper pipe:	Hot water	.1250
	Cold water	.1600

Experiments with brass, galvanized iron and lead-lined pipes were also made at this time with the waters shown in the following table, and in these experiments the water was allowed to remain in the pipes one week in each case and the pipes were in use a portion of each day between experiments.

The Lawrence water is a sand-filtered surface water, into which considerable ground water enters at the filtration plant; Merrimack River, the Lawrence supply before filtration; a filter effluent, a surface supply sand-filtered; North Andover supply, a surface water, and Methuen, a ground-water supply. A study of the table shows that much zinc and lead were taken into solution by these supplies in these experiments and but a comparatively small amount of copper. Generally speaking each supply took 40 or 50 times as much zinc as copper and the relation between the lead and the copper was about the same. It is noticeable that the surface supplies took less and less metal from the pipes as they continued in use, while the amount taken by the one ground-water supply, Methuen, continued about the same. It will be noticed that at the end of these experiments the Lawrence supply absorbed only about one thirty-fifth as much copper as zinc and one nineteenth as much copper as lead, and the filter effluent about one twentieth as much copper as zinc and one thirtieth as much copper as lead. These experiments were with new uncoated and uncorroded pipes.

COPPER.

(Parts in 100 000.)

Lawrence supply	0.0628	0.0314	0.0000	0.0571	0.0486	0.0514	0.0400
Merrimack River	0.0371	0.0600	0.0400	0.0743	0.0514	0.0686	0.0543
A filter effluent	0.0713	0.0171	0.0200	0.0086	0.0086	0.0171	0.0171
North Andover supply	0.0086	0.0114	0.0114	0.0200	0.0286	0.0200	.....
Methuen supply	0.0171	0.0171	0.0200	0.0314	0.0571	0.0571	.....

ZINC.

Lawrence supply	2.9000	1.8800	0.7800	1.3900	1.2400	1.4350	1.3550
Merrimack River	1.4200	2.8500	2.8100	2.2400	1.8500	1.8300	1.9200
A filter effluent	1.9290	1.2600	1.3500	0.6750	0.0600	0.7250	0.3300
North Andover supply	5.4740	0.9400	4.8400	3.5200	3.4600	2.4100	.....
Methuen supply	1.8200	3.5400	3.2500	2.1000	2.0000	2.1600	.....

LEAD.

Lawrence supply	1.6000	1.7100	1.7850	0.9710	0.8000	.....	0.7429
Merrimack River	4.0000	6.8570	4.2860	2.5140	0.9140	.....	0.6857
A filter effluent	0.7080	0.8750	0.8230	0.4570	0.4290	.....	0.5368
North Andover supply	0.5710	1.6000	0.8930	0.8570	0.2860	.....	0.3000
Methuen supply	0.4290	0.7430	0.6800	0.5430	0.6290	.....	0.7714

Other work interfered with the continuation of these experiments but during 1925, 1926 and 1927 up to date, further work in regard to the action of various waters upon brass and copper pipes has been continued, pipes 25 ft. in length having been installed for this purpose in the cities of Newton, Lowell, Lawrence and Boston. The Newton supply is a ground water;

the Lowell, a ground water filtered for the removal of iron; the Lawrence, a filtered surface water into which some ground water enters, and of course Boston, has the Metropolitan supply. There is added also to these results 20 from a copper pipe about 200 ft. long and installed by Mr. Finneran of the Boston Water Department in their headquarters on Albany Street. These results are summarized in the following table:

COPPER AND BRASS PIPES EACH 25 FT. IN LENGTH.

STANDING SAMPLES.

COPPER.

(Parts in 100 000.)

Time water stood in pipe.	BOSTON.		LAWRENCE.		NEWTON.		LOWELL.	
	Copper pipe.	Brass pipe.	Copper pipe.	Brass pipe.	Copper pipe.	Brass pipe.	Copper pipe.	Brass pipe.
1925.								
24 hours	.0429	.0086	.0086	.0143	.0429	.0457	.0400	.0571
24 hours	.0343	.0286	.0229	.0457	.0371	.0457	.0171	.0286
48 hours	....	....	....	....	.0114	.0200	.0114	.0200
48 hours	.0429	.0143	.1029	.0143	.0086	.0114	.0171	.0229
8 hours	.1086	.0229	.0229	.0629	.0057	.0171	.1314	.0686
1926.								
8 hours	.1143	.0171	.2860	.1714	.0000	.0000	.3200	.0857
8 hours	.2000	.0171	....	....	....	....	....	....
8 hours	.1143	.0286	....	....	....	....	....	....
8 hours	.1257	.0000	....	....	....	....	....	....
24 hours	.0327	.0236	.3863	.3384	.0105	.0289	.2000	.0371
3 days	.0900	.0649	.0501	.1300	.0100	.0200	.0249	.0200
9 months, 27 days	....	....	.0421	.0649	.0318	.0401	.0267	.0532
7 days	....	....	.1100	.1500	.0249	.0400	.0200	.0100
1927.								
7 days	.0352	.0100	....	....	....	....	....	....
Average	.0855	.0214	.1146	.1102	.0183	.0269	.0809	.0403

RUNNING SAMPLES.

1925.								
0 hours	.0000	.0000	.0000	.0000	.0200	.0000	.0000	.0000
0 hours	.0200	.0171	.0000	.0000	.0057	.0000	.0057	.0000
1926.								
0 hours	....	....	.0400	.0152	....	....	....	....

The following facts can be drawn from an examination of these results from brass and copper pipes: (1) Nearly all of these analyses showed copper to be present in less than 0.10 part in 100 000 but occasionally larger amounts were found. These larger amounts may have been due to corrosion or to the loosening of infinitesimal particles of metal from the pipes and collection in the samples; (2) the results from the different supplies

do not vary enough to draw any definite conclusions as to the relative corrosiveness of ground or surface waters. If anything the Lawrence supply would appear to be the most corrosive but this is a supply from an exceedingly polluted river into which all kinds of organic and other wastes enter, and possibly at times enough copper is present to exaggerate the corrosion results; (3) judging from the results it is immaterial as far as copper in the water is concerned whether brass or copper pipes are used. Generally the greater amount of copper was found in the samples from the copper pipes but the brass pipes offer less copper surface to the water than do the copper

BOSTON.

COPPER PIPE 200 FT. LONG.

COPPER.

(Parts in 100 000.)

Year.	Time water stood in pipe.	Standing sample.	Running sample.
1926	24 hours	.0466	.0241
1926	48 hours	.0451	.0025
1926	95 hours	.0250	.0050
1926	7 days	.0650	.0150
1926	24 hours	.0600	.0125
1926	47 hours	.0600	.0175
1927	95 hours	.0600	.0125
1927	7 days	.0274	.0074
1927	24 hours	.0452	.0074
1927	48 hours	.0252	.0074
Average		.0459	.0111

pipes owing to the fact that brass contains a large percentage of zinc and these pipes yield much more zinc than copper. For this reason they are probably shorter lived. We have had in the laboratory many brass pipes the walls of which showed the great loss of zinc by corrosion and the slight loss of copper; (4) the 200-ft. pipe installed by Mr. Finneran seemed to yield the most uniform results. It was long enough, moreover, to show copper in the running samples. The average results from all these places are given at the bottom of each table. As I have several times mentioned, and wish to emphasize, all experimental results are from new, uncorroded experimental pipes and not from service pipes in actual use. Undoubtedly on account of this the amount of metal taken into solution is greater than from older pipes. The relative corrosion, which the experiments are for, is, however, shown more clearly by these experimental pipes of equal lengths and of the same quality of brass and copper than could be shown by results from old service pipes.

Summary.

Summarizing the results of these investigations it is evident that whatever pipe is used a certain amount of metal will be taken into solution by the water and this amount varies under different conditions and with different waters; that if the pipe is iron a greater amount is taken than from a pipe of any other metal. Galvanizing an iron pipe prevents to a large extent and for a considerable period the absorption of iron but much zinc is continually taken into solution as long as the galvanizing lasts. Tin-lined pipes are awkward to handle from a plumbing point of view but little tin is taken from them by any water. Brass pipes yield much zinc but generally only minute amounts of copper. Copper pipes yield about the same amount of copper as the brass pipes but zinc is not involved in the corrosion of these pipes except occasionally, certain copper pipes seeming to contain a small amount of zinc. We know from experience in this state that lead in average amounts of .04 of a part in 100 000 in drinking water will cause lead poisoning of certain individuals if habitually used. Occasional statements have been made by certain investigators in regard to the harmfulness of zinc when present habitually in amounts greater than 2 or 3 parts in 100 000. We have no recorded instances of intestinal or other troubles from zinc in water although this zinc is present in large amounts in practically all waters passing through galvanized iron pipes. It seems hardly possible that the small amount of copper taken generally from brass or copper pipes can cause illness but probably every house piping system should be well flushed out each morning in order that the water which has stood in the pipes overnight may be removed.

In some of this work minute amounts of copper were found in ground and surface waters which had not passed through copper pipes. This is not a cause for surprise as the human system always contains copper taken in with food and of course it is being constantly removed from the system. Shellfish, especially oysters, contain considerable copper and such grains as wheat, barley, etc., also contain copper which must come from the ground. Brass strainers on driven-well systems also yield copper and zinc.

I am also presenting a table from an article by Dr. John C. Thresh, a well-known English chemist. This article was published in the *Lancet* nearly a year ago. You will see from examination of this table that the results given in parts in 100 000 are very similar to the results obtained by us in connection with the examination of Massachusetts supplies, the copper found varying from none to over one part in 100 000 in one instance, but most of the results are comparatively low. Dr. Thresh made this investigation on account of a question asked him in regard to the use of copper pipes in a public institution and also at the request of the Copper and Brass Users' Association. In his article he states that the amount of copper found did not vary with the class of pipe used, electrolytic copper, copper pipe complying with the specifications of the British Engineering Standards Association and a third grade, the G. P. standard copper, being tested.

While I shall not enter into his discussion of the various phases of his investigation his conclusion was that where the average amount of copper in the whole day's supply of drinking water does not exceed 0.1 of a grain per Imperial gallon, that is, 0.14 part in 100 000, the water can be considered as perfectly wholesome, and he quoted from the *English Manual of Pharma-*

TABLE FROM ARTICLE BY DR. THRESH.

	Copper* (Parts in 100 000.)
River water of moderate temporary hardness:	
London	0.04
Surrey	0.025
Hampshire	0.035
An unfiltered river water	0.06
Deep well waters:	
Chalk	0.000
Limestone	0.05
New red sandstone	0.01
An alkaline water:	
Thanet sand	0.04
Thanet sand	0.025
Greensand water:	
Hardness 5.2	0.01
Moorland water:	
Hardness 5.2	0.033–0.065
Hardness 3.9	0.01
Hardness 1.3	0.057–0.075
Hardness 1.3	0.15
Hardness 3.6	0.15
Hardness 1.3 (very acid)	0.65
Acid neutralised with chalk	0.01
Hardness 3.0	0.05
Hardness 5.2	0.00
Hardness 0.6	0.10
Hardness 5.2	0.045
Hardness 6.5	0.06
Spring water:	
Hardness 27.3	0.05
Hardness 3.9	1.075
Hardness 19.5	0.06
Very pure distilled water:	
Hardness 0.0	0.14–0.20
+ 4 mg. $MgCl_2$, hardness 5.2	0.020
+ 4 mg. NaCl, hardness 0.0	0.01

*Copper taken up in 24 hours.

cology and from Dr. Dixon Man in *Forensic Medicine and Toxicology* to prove that there is no evidence that man is ever affected with chronic copper poisoning from the use of copper cooking vessels and that the existence of chronic copper poisoning is unknown. He stated that copper pipes can be used for all waters which are not acid in reaction but that such waters should not be used until the acidity has been removed by treatment. English chemists speak of acid waters freely but seldom make any statement as to the cause of the acidity. Dr. Thresh did show in one instance that the amount of copper taken up by a boiling "acid" water in 48 hours was more than 20 times that taken by the same water cold, but that a neutral water as he called it, did not take up, even when kept at the boiling temperature for 48 hours, more than from 0.03 to 0.06 part in 100 000. The water must have had mineral rather than carbonic acidity.

Finally, I wish to call attention to the very minute amounts of these metals found in most of these corrosion experiments. We are accustomed to see our results stated in parts in 100 000. This given in milligrams means that if the water contains 1.0 part in 100 000 of copper 1 mg. is present in 100 cubic centimeters of the water or about 37 mg. in a gallon. Now if our average "standing" results are, say, 0.05 part copper in 100 000, more than half a gallon of water which has stood in the pipes for several hours must be drunk daily to take into our system a milligram of this metal. English authorities state that each individual takes into his body daily 20 mg. of copper and that so long as the total quantity of copper ingested does not exceed 100 mg. daily there can be no question of injury to health. 100 mg. would be about the amount we should find in 54 gal. of water when there is 0.05 part in 100 000. Our average results from "running" samples after the pipes are flushed are not greater than 0.0150 part in 100 000.

In this work studies have been made of carbonic acid, dissolved oxygen and hardness and in recent work of the pH of the waters. So far as we can ascertain the pH determination has some significance in giving information of corrosive properties but must be studied in connection with other analytical determinations.

We have been accustomed to think of our surface waters as alkaline and they are by practically all chemical tests. Our ground waters are practically all slightly acid on account of the free carbonic acid present. By the pH test, however, most of our surface waters are also acid.

When water is placed in a brass or copper pipe for a number of hours or days the dissolved oxygen and CO_2 should decrease in amount as corrosion occurs and also the hydrogen ions, that is, as the CO_2 becomes exhausted or consumed the acidity of the water is decreased. A number of studies have been made, sometimes with more or less confusing results, but often these results are about as they theoretically should be as shown in the following table:

STUDIES of CO_2, pH, ETC., IN WATER ENTERING AND COMING FROM BRASS AND COPPER PIPES.

	GROUND WATER.			SURFACE WATER.		
		COMING FROM			COMING FROM	
	Entering pipe.	Brass pipe.	Copper pipe.	Entering pipe.	Brass pipe.	Copper pipe.
*Alkalinity	3.30	3.20	4.20	1.50	2.50	2.30
*Carbonic acid	1.41	0.22	1.28	0.26	0.18	0.13
Oxygen (per cent.)	72	61	37	100	81	100
†pH	6.3	6.7	6.8	6.6	6.8	6.8
*Alkalinity	4.50	4.40	4.30	1.60	2.10	2.80
*Carbonic acid	2.11	2.07	0.35	0.35	0.26	0.18
Oxygen (per cent.)	57	54	53	100	79	81
pH	6.3	6.7	6.5	6.5	6.8	6.7

*Parts in 100 000.

† Figures below 7.0 denote acidity; above, alkalinity.

Discussion.

George H. Finneran.* At the present time and for 80 years past, Boston has used only two materials for its service pipes — cast-iron and lead. There may have been laid at various times during that period a few pipes of wrought-iron, tin-lined lead, lead-lined iron, cement-lined iron, brass, or block tin, but the total numbers of each and all, are not sufficiently large to receive consideration.

Cast-iron for large-sized services has proven satisfactory. It sometimes breaks because of unequal support, but if properly laid and protected, will give good service. For small-sized services it is not so satisfactory because of the rust-forming properties of Boston water.

We have never felt that as a material for small-sized service pipes there was anything decidedly better than lead and, therefore, have continued its use in the department thus far.

There was considerable apprehension during the early days over the possibility of lead poisoning, but Professor Horsford of Harvard University, a well-known chemist of that time, assured the nervous ones that there was nothing to fear. In his study of the matter he found that upon the passage of water through new lead pipe, a protective film was produced that adhered to the interior surface and remained there during the life of the pipe, a barrier as it were, between the lead and the water, preventing any deleterious chemical action.

We all know how easily lead pipe may be handled and worked. We also are aware of its non-corrosiveness. There are times, however, when we have found it transformed into a hard and brittle substance by the action of soil. We have also found it devitalized and destroyed by electrolysis. It is also susceptible to minor injuries from pick points, nails and the gnawing of rats, and many times we have wished it possessed more tensile strength. We know how it expands and bursts when the water inside freezes, and during the last few years, our attention has been attracted to the increasing number of bursts in lead pipe of large size, due, as it seems, to quick closing fixtures now so much used in modern plumbing.

In Boston, we no longer use lead pipe for services of two-inch diameter. We are using cast-iron pipe. It is our frequent experience, especially with two-inch supplies carrying pressures of about 90 lbs. or more, that the lead pipe "balloons out" similar to that part of an automobile inner tube where the surrounding casing or shoe is soft and weak. These "balloons" eventually burst and give us trouble.

We find, as a rule, pipes that develop this trouble enter buildings that have flushometers, hydraulic elevators, and self-closing faucets. It is our opinion that the quick closing of these fixtures starts a water-hammer that spends more or less of its force on the walls of the lead pipe.

We are also troubled to a considerable extent with failures of lead pipe

*Superintendent, Water Service, Boston, Mass.

at points where couplings are attached. This may be due to settlement; it may be due to workmanship; it may be due to the inherent properties of lead pipe; or it may be due to a combination of factors. At any rate, it disturbs us, and discourages a feeling of snug contentment.

Because of our experience with cast iron and lead as briefly stated in the following, our minds were somewhat receptive when the eloquent and persuasive representative of Mueller Company visited us and recited the wonderful qualities of copper pipe. He so impressed us that we threw moderation to the winds and plunged to the extent of 200 ft. of $\frac{3}{4}$-in. copper pipe, with the intention of trying it out.

After indulging in this orgy of buying, we set out to use it experimentally, but just then we hesitated as the thought grew in our minds that possibly some of the copper might dissolve in the water and cause more or less sickness. We had read much of copper poisoning, and we were not inclined to inflict the consumers of Boston with a disease of such seriousness. We, therefore, had recourse to our very efficient State Board of Health.

The matter was placed before Mr. Weston of that body and it was agreed that the water service of the city of Boston should, with the assistance of the chemist of the State Board, conduct an experiment to determine if metropolitan water would take up copper in dangerous quantity in its passage from the main to the consumer through a copper pipe of the composition of that sold by the Mueller Company.

Accordingly apparatus for a test was devised and set up as follows:

A large wooden drum, somewhat similar to those upon which underground cables are carried, was constructed by our carpenters and set up in our plumbing shop. Its diameter is about five feet and the width of the rim about two and one-half feet. It has a piece of iron pipe passing through its center which acts as a shaft, the ends of which are supported by uprights on each side. By this arrangement the drum may be revolved and the winding of the copper pipe upon its rim, facilitated.

Two hundred feet of $\frac{3}{4}$-in. copper pipe made up with the special couplings provided, was wound around the drum and one end was connected with a faucet in the shop by a short run of about 15 ft. of $\frac{3}{4}$-in. lead pipe. This served as the inlet pipe to the copper coil. A meter was set in this inlet pipe. Attached to the other end of the copper coil was a run of about 15 ft. of $\frac{3}{4}$-in. lead pipe which served as a discharge into the shop drainage system.

Acting under instruction of Mr. Clark of the State Board of Health, water was started running through the coil at 3 P.M., December 3, 1926, and allowed to run through at fairly good velocity until 3 P.M. December 6, when the cock controlling the discharge end was shut off and remained off until December 7. As the cock on the inlet end was open the water in the coil was under pressure. At 3 P.M., December 7, a representative of the State Board of Health appeared and drew off a sample of the water in the coil and from then until a week or ten days ago, he collected samples of varying

age and conditions, which were analyzed and about which Mr. Clark told you in his paper today. About 12 000 gal. of water passed through the coil during the period of test.

DR. JOSEPH C. AUB.* I did not come prepared to talk, and I did not know I was going to be called upon.

I think of the investigations we made — Dr. Fairhall, several others and myself — on lead poisoning, only two or three things would interest you. First of all, the human body is very much like hard water that runs through lead pipes and dissolves but little lead, as Mr. Clark said. We have a great deal of calcium in our bodies, and it is this calcium and the phosphate which protects us from lead poisoning. The lead gets into the body and is deposited largely in the bones, in the calcium, and therefore is stored but not circulated around in the body very much, and is therefore no more toxic than it is. This fact, and the fact that lead is fairly insoluble at the reaction of our body, makes lead far less poisonous a substance than would otherwise be the case. The second reason why there is not much lead poisoning from water pipe now, is the fact that it is taken in by the mouth, and lead is a great deal more poisonous when taken in by the lungs than when taken into the stomach, because part is never absorbed by the intestines, but is excreted.

We made some observations which ought to be of interest to you. I have been looking for lead poisoning for many years, and it is surprising to me the small number of cases one sees which one can attribute to water alone. They are not common, and those we see are mild cases. As a result, when we were working on this problem we analyzed bones of people who had been living in or near Boston for a long period of time. These were autopsy cases. Thus we could determine whether the individuals had absorbed lead during their lives, because nearly all the lead that is retained by the body stays in the bone, and if you analyze the bones for lead you will find out if an appreciable amount of lead was stored by individuals who were getting it from drinking water and not from their occupations. I do not remember the statistics exactly, but practically none had any appreciable amount of lead stored in their systems. In other words, they had retained practically no lead from the drinking water during their lifetimes. Therefore, I should think that lead from this water system around Boston, as a factor of danger from lead poisoning, is practically negligible. By that I do not mean to say that one cannot get lead poisoning from the water supply. You certainly can get lead poisoning from improper water supply, particularly from wells, where there are lead pipes going into the wells, and where the water is acid, and where the individual repeatedly drinks the water that has been standing in the lead pipes. But when one thinks of the large amount of lead pipe around Boston, and the fact that there is practically no lead stored in the system of a person drinking this water after many years, it seems that the danger is very small from a prop-

*Massachusetts General Hospital, Boston, Mass.

erly operated water system such as we have here. If we have acid water, it is a different matter.

A case comes to my mind of a painter who came to me two years ago with a complete arm paralysis, which was the characteristic lead paralysis. He was made essentially well — as well as he could have been under the circumstances. Then, to be perfectly safe, I sent him out to the country on his son's farm to work, so that he would never be exposed to lead again. He worked there for three or four months and was very happy — he was a relatively old gentleman — feeling he was again in good health, but one morning he woke up and found he was paralyzed again. We analyzed the water of his well and found much lead. He had been unfortunate enough to have struck a well that had lead pipe running into it and he had a marked recurrence of his lead poisoning.

ROBERT SPURR WESTON.* I am very much impressed by the papers we have heard, especially Mr. Clark's paper. It was so brilliant and stimulating that I doubt whether he really stayed on that water wagon all the time.

In this whole question of the action of water on metals, one ought to bear in mind four factors which affect the result, namely: the dissolved gasses in the water; the composition of the water; the metal with which the water comes in contact; and the protective coating which is formed upon the pipe, either artificially or naturally.

Boston has not suffered from the water supply for a great many years. In the early days it came from the Cochituate and Framingham sources. We have not suffered because of the protective coating of organic matter which forms inside of the pipe. As the water gets better in quality; as the amount of organic matter decreases by more storage, and if filtration should be practiced, we may expect in the future a little more action on service pipes in the Metropolitan District than we have experienced in the past.

Perhaps I can illustrate by two or three typical cases of copper poisoning which have arisen in our practice. The first case was nearly 30 years ago. A prominent family which had a country house near Boston, took its water from wells and pumped it into elevated tanks, from which it ran two or three hundred feet, as I remember, through a 2-in. galvanized iron pipe, to the house. Naturally, after the zinc dissolved away through, the action of this aërated ground water, which of course was very corrosive the iron remained, was carried into the house and rusted all the plumbing fixtures. The plumber was consulted. He said, "Why not put in the best thing you can buy, 'Admiralty' copper," which is not, as you know, attacked by salt water, being used in condenser tubes and on marine engine installations. This advice was acted upon and soon the lady-of-the-house developed a real case of copper poisoning; the copper pipes had to be removed and iron replaced. The corrosion in that case was due to the water, which contained oxygen and carbonic acid, and which had no substance in

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it, being a soft ground water, to form a protective coating on the copper.

Another case which came up recently was in Brookline, where, as you know, they are supplied with a water that is aërated and filtered, in the course of which the carbon dioxide gas is reduced from, roughly, 50 p.p.m. to 5 p.p.m., and the water is nearly saturated with oxygen. This water, as you know, dissolves zinc from brass pipe very readily. In one case in Brookline the plumber advised, as in the first case I mentioned, the substitution of brass pipe or galvanized pipe — I have forgotten which — with copper. This copper was attacked very actively, and so actively that a sponge remaining all night beneath the dripping bathtub cock was colored green. This was on the hot water system, and there the corrosion was due largely to the action between the metals; that is, the copper pipe had been connected with a pipe of some other metal and galvanic action had occurred. In this case the interposition of an insulating coupling between the two metals prevented the recurrence of notable staining of the plumbing fixtures.

A third case occurred where a whole supply was treated with sodium silicate to prevent the corrosion of lead, and the doses of sodium silicate were reduced to a low point when practically every new brass pipe installation in town was attacked by the water. This was a ground water containing oxygen and carbon dioxide.

These, I think, gentlemen, are typical cases of copper poisoning.

Just a statement of an opinion which appears to be gaining ground and recording an advance in sanitary science, namely, that quantities of lead and copper and zinc which were formerly considered non-poisonous are now being considered posionous by the pathologists and physicians who are experts in such matters. I feel sure that water-works managers and engineers will have to set a higher standard for the solution of metals by water in the future than they have in the past.

DR. HERBERT D. PEASE.* Mr. Chairman and members of the Association. I am extremely interested in both the papers of the afternoon. I am somewhat familiar with Dr. Mallory's work, having had the opportunity of seeing some of his experiments and results, and I have been very much interested in the correlation of Dr. Mallory's remarkable work, with the equally remarkable work of Mr. Clark and his associates.

I agree with what Mr. Weston has just said in respect to the amounts of copper and metals which are now considered toxic as compared with the old ideas of the toxicologists. We should follow in the footsteps of the medical investigators, of which Dr. Mallory is one of our very great leaders, and be very careful not to be misled by the ideas embodied in the much older literature of the toxicologists. They had to note very massive toxic effects before they were willing to pronounce anything of a toxic or infectious nature. With the refined methods, some of which are even much more delicate than Dr. Mallory has mentioned here this afternoon pro-

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ducing in long-time periods these massive effects on the liver and the other organs, we can determine toxic effects on individual cells and on the functional processes of some of these cells. I have in mind such studies as those on the fertilization phenomena in sea urchin eggs. The results of these studies indicate that very minute degrees of toxic actions may be of very considerable importance. Investigators in certain medical fields have carried the dilutions of certain toxic metals to such extents that they have been able to demonstrate very minor but unmistakable stimulative effects of some of those metals but which in very slightly larger doses give equally definite toxic effects.

When we now speak of toxicity, we should make sure that we are not likely to be interpreted as speaking from the points of view of the older toxicologists.

Those are just one or two of the things that come to my mind, although I must say that the water wagon this afternoon has very much on the perhaps more stimulative pathological wagon.

PROF. MELVILLE C. WHIPPLE.* I have been very much impressed by the papers this afternoon, and I think we have learned a great deal. As to the likelihood of tap water being the cause of observed cases of copper poisoning it is very reassuring to have Dr. Mallory give the Scotch verdict of "not proven." I feel, however, as he probably does, that there is yet much to learn about copper in water and its toxicological effects. With greater knowledge we shall hope to be able some day to return the more decisive verdict of "not guilty."

There are two or three ways in which the question of copper and its effects upon consumers touches the water-works fraternity. One of them is in connection with the use of copper sulphate for the killing of algæ in reservoirs and ponds. I think that the rather limited use of copper sulphate for this purpose, particularly in this part of the country, has been largely due to doubt in the minds of many as to whether or not the copper introduced into water at such times may have an effect upon the consumers. We know that in the case of some supplies treated with copper sulphate the metal comes through to the taps, but as to whether it is significant in quantity is a different question. If, as Dr. Mallory mentioned, the tolerance for copper may be five or ten milligrams a day (the value is not established), then it is not likely, it would seem to me, that the amount of copper which is used, and which comes through the taps after treatment of reservoirs, can be of significance.

We are also concerned with copper in water in connection with the growing use of copper pipes for various purposes. I think it is significant to look at Mr. Clark's results and see that in nearly all cases the amount of copper reported, and lead and zinc as well, exceeds certain standards which are in existence today — that is, the standards which have been set up by the United States Public Health Service for the interstate carriers of water.

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These are the first standards for drinking water that have prescribed the amount of heavy metals that may be present. In the case of copper the allowable limit is 0.2 p.p.m., or 0.02 of a part per one hundred thousand; in the case of lead it is 0.1 p.p.m.; in the case of zinc 5.0 p.p.m. A great many of Mr. Clark's results indicate that these quantities were exceeded in the tests. No doubt the standards have incorporated a very large factor of safety; nevertheless I think, as Dr. Pease says, that in the light of some of the knowledge that toxicology and other sciences have contributed we must be careful to interpret information on this subject in the light of newly acquired facts and not according to conceptions that were formed before these facts were known.

MECHANICALLY CLEANED SEDIMENTATION BASINS FOR WATER WORKS.

BY EDMUND B. BESSELIEVRE.*

[*Read September 16, 1926.*]

Mud, silt, sand, and other suspensa, transported by surface waters into the intakes of municipal and industrial water supplies, have long been the source of much expense and trouble in the operation of water treatment plants.

Mud balls on filters, frequent rewashing because of reduction of capacity due to clogging, and, in slow sand plants, the laborious process of removing the filter medium and cleaning it, have without doubt been due to the periodic or continual excess solids and turbidity in surface water.

Spring freshets, drainage from farms and adjacent lands, pollution by sewage and industrial wastes, are some of the causes of this excess operating burden. To remove some of this trouble, it has been the custom, when the turbidity was due to solids held in suspension only during high velocity stream flows, or was of such a nature that with a reasonable time of detention the bulk of the material would settle, to provide sedimentation basins as the first units in the plant. This was an advance in practice, but it still presented some features of operating difficulty.

The settled solids gradually depositing in the settling tank filled this unit to such an extent, that, in order to maintain any degree of efficiency, it was necessary to shut down the unit, draw off the supernatant water, and flush out, or in many cases dig out, with buckets or shovels, the accumulated solids. This introduced two elements of expense, first, initial expense because an additional unit was usually provided to be used when one unit was shut down for cleaning, and, second, operating expense for the manual labor required for the actual removal of the sludge and expense for the water used in flushing the tank. The frequency of these periodic shutdowns and cleanings depended, of course, upon the water used and the usual or occasional increase in solids. But cases have been known where sedimentation tanks filled clear to the top in a few weeks, especially in the southwestern part of the United States. Even in cases in the eastern states, however, this method of cleaning has become such a serious financial burden that the engineers have been searching for a more economical means of operation.

A self-cleaning sedimentation unit had been developed and used successfully in sewage and industrial waste treatment plants, and it was realized that this unit would function equally successfully in water plants. This unit comprises a simple concrete basin, rectangular in shape, with sides of

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approximately equal length, inflow over the entire length of one side, and discharge over weirs the entire length of the side opposite the influent. The basin contains sufficient volume to give the desired theoretical retention, and it is provided with proper baffles at the influent side to prevent cross currents, and with scum boards at the effluent side.

As no provision for sludge accumulation is necessary, this unit may be shallow, many of them being built with water depths of seven feet. The bottom of the tank slopes equally, on a slight slope, to a central sludge cone, and the unit is equipped with a mechanism (which operates continuously) for collecting the settled solids and carrying them to the central sludge cone where they may be continuously discharged through a nozzle (as at South Pittsburgh) or taken out by a suitable pump.

Obviously, any mechanism which moved fast enough to stir up sludge would be useless in a sedimentation unit, so the clarifier mechanism moves very slowly; i.e., in a tank 100 ft. square, it makes only three complete revolutions an hour. Slow motion means little power consumed and consequently low cost of operation.

The apparent features of advantage, of such a self-cleaning sedimentation unit, are:

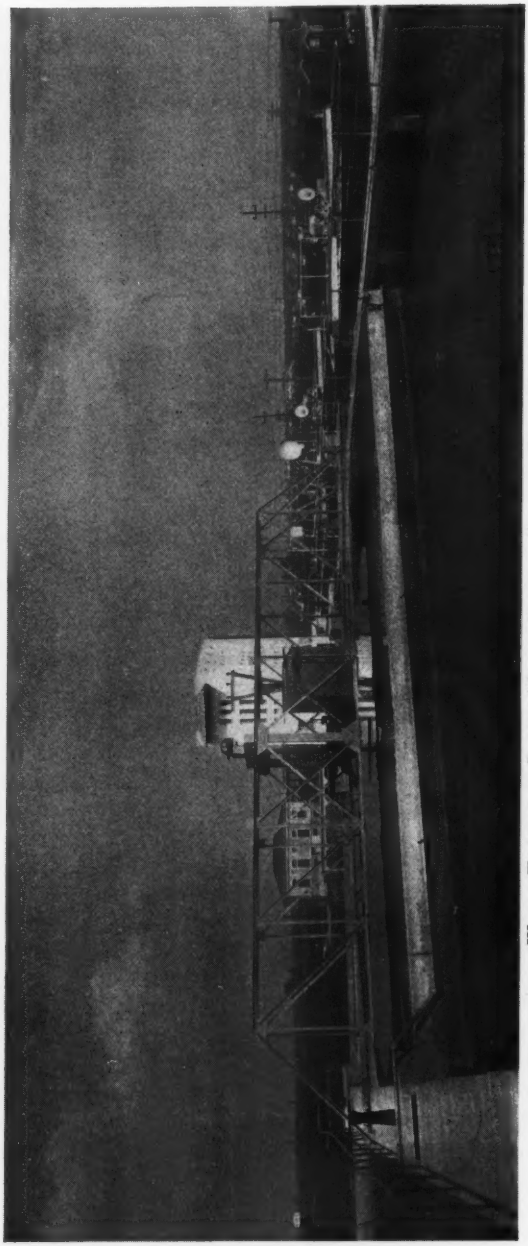
1. Freedom from manual cleaning.
2. Continuous operation.
3. Elimination of duplicate units in any but very large plants or those subject to heavy fluctuations in flow.
4. Low cost of operation.
5. Maintained efficiency of the unit as regards detention period.

Besides these advantages, there is a strong point of advantage, in that, by using a tank of this kind, removing the same amount of solids each day, as the amount that has been deposited in the tank, the danger of increasing pollution of the water, bacterially, is removed. Waters, carrying large amounts of organic solids that are deposited in a settling tank and allowed to accumulate, are subjected to the increasing pollution due to the putrefaction of these organic solids. It is true that this pollution is removed by filters and by the disinfectants used in many plants as a final shot, but the removal of these organic solids from the tank, before they become putrescent, could not fail to reduce the load factors on the other units of the plant.

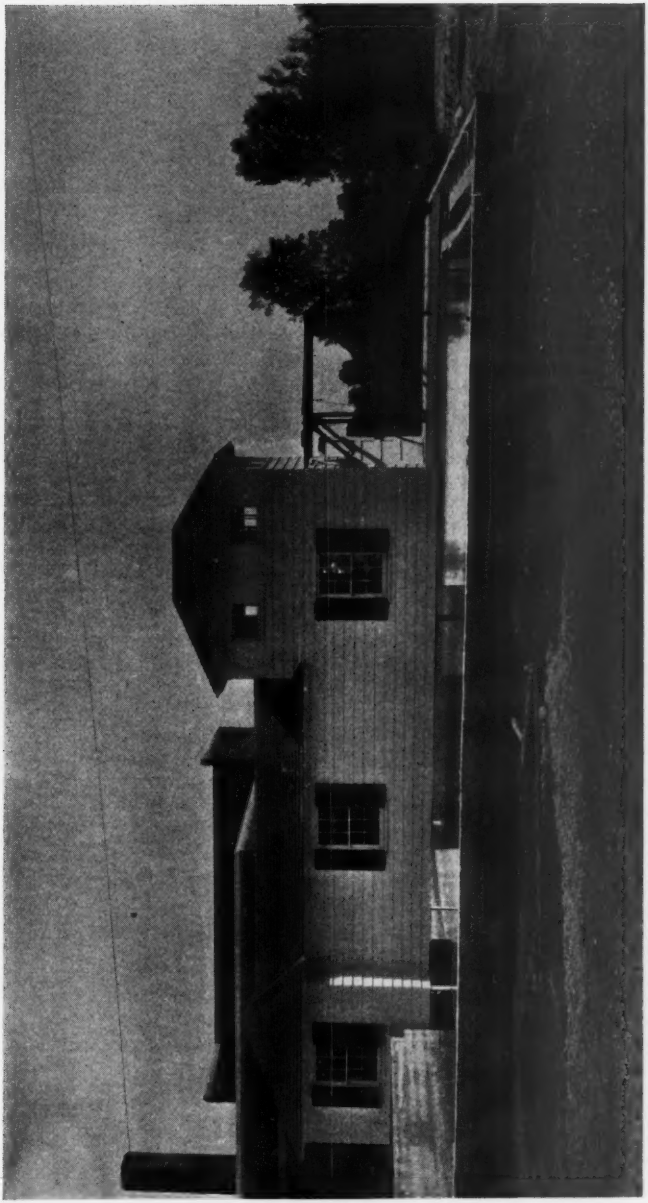
Still another feature is that it is sometimes difficult to dispose of a large amount of mud dug out of tanks, in a short period, whereas if a smaller amount is discharged, daily, it can usually be run back into the stream below the intake, or used as fill.

That operation costs are low may be best shown by the fact that a unit of this type, 200 ft. in diameter, which has been handling water containing a large amount of solids, for several years, requires an input of only 2.8 h.p.

Not only does the clarifier mechanism prove beneficial in collecting the sludge, but definite tests have shown that the action of this particular type of mechanism, in conveying the sludge to the central discharge cone, pro-



WATER TREATMENT PLANT, MIAMI, FLORIDA, SHOWING DORR CLARIFIER.



DORR CLARIFIER INSTALLATION AT WATER TREATMENT PLANT AT PIQUA, OHIO.

duces a sludge of greater density than can be secured in plain sedimentation units. This means less sludge to handle, a decided economy if pumping is required, and less waste of water. A series of recent tests show that sludges of 7 to 10 per cent. greater density can be procured from a clarifier than from a plain tank with the same time interval. Where sludges containing 14 to 15 per cent. of solids were obtained in plain tanks, the clarifier sludge, on the same test, ran from 22 to 24 per cent. of solids.

At Kansas City, Mo., and at other places on the Missouri and Mississippi Rivers, where turbidities occasionally run as high as 28 000 p.p.m., it has been demonstrated that with two to three hours of sedimentation, 91.7 to 99.0 per cent. of this amount can be removed; and the beneficial effect of this in plant operating expense can readily be appreciated. At the new water treatment plant for Kansas City, Mo., there are being installed four units, each 200 ft. in diameter, for the sedimentation of the raw Missouri River water, before passing to the filters. A recent series of tests, concluded on the waters from a western river, using a small clarifier unit (26 ft.) as a sedimentation basin, showed that with three hours' detention, removals of 92.8 per cent. of the suspended solids and 91.7 per cent. of the turbidity were obtained. This indicates that not only the coarser suspensa are removed, but also the finer solids. In this case the raw water contained 5 844 p.p.m. of suspended solids and 8 390 p.p.m. of turbidity.

Where the solids are such that a reasonable period of sedimentation, up to four hours, will remove 90 per cent. and over of these solids, it is economical to include, in the plant, self-cleaning sedimentation units as described.

In water softening plants it has been customary to add a series of sedimentation basins, to catch the precipitate, and to dewater these periodically for the purpose of cleaning. The clarifier has been adapted to this field and a number of operating installations have shown decided benefits to be derived. At Newark, Ohio, one of the first applications in a municipal water softening plant, a report of the chemist in charge* shows the following results:

AVERAGE OF TEN SETS OF SAMPLES TAKEN FROM THE DORR CLARIFIER OVER A PERIOD OF THREE WEEKS.

	Parts per Million		
	Influent	Effluent	Percentage Removed
Suspended material	586	6	98.9
Total alkalinity	42	40	...
Basicity mono carb. alk.	32	32	...
Caustic alkalinity	10	8	...

The above results represent normal conditions when the turbidity of the raw water is very low. The effluent remains just about the same, even when turbidities are as high as 1 500 p.p.m., that is, providing the chemical treatment is right.

* The Municipal Water Treatment Plant at Newark, Ohio. — C. T. Kaiser, Chemist in Charge. *American City Magazine*, December, 1925.

These results were obtained with a nominal detention period of only twenty-two minutes, when handling 6 million gal. a day. The clarifier is 40 ft. in size, with a water depth of 8 ft.

At the South Pittsburgh (Penna.) Water Company's new filtration and softening plants, a unit 80 ft. in size is used to treat a maximum flow of 20 million gal. a day. At this unit, continuous sludge discharge is obtained through a nozzle.

In a recent paper* discussing new features of water purification in Ohio, the following is stated in reference to the results obtained at several plants in Ohio where units of this type are used:

"Municipal water treatment practice has copied from industry another device, the clarifier, which has been developed largely by The Dorr Company. There are three in service in Ohio, all three of them in connection with water softening installations. The character and volume of the precipitate resulting from the raw water treatment determines to a large extent the advisability of installing thickening devices of this nature. For the most part turbidities are not encountered in Ohio, that would warrant the installation of clarifiers in ordinary water treatment practice. The three softening plants employing Dorr clarifiers are the ones at Newark, Greenville, and Piqua. The first installation was circular in style, but the two recent ones are square. The water is retained about one hour and permitted to flow through the clarifier at a low velocity of travel somewhat less than one-half ft. a minute. The mechanically operated thickener is set for a slow rate of travel usually about four revolutions an hour.

"The advantages of the clarifier particularly for water softening practice are seen from the results cited for the Newark plant. The clarifier removes about 98 per cent. of the total suspended matter present in the water, leaving the mixing chamber. Another advantage is that sludge removal may be conducted continuously and in less objectionable manner. This item is of particular importance where a small stream must receive the discharge of the sludge and waste water from the purification works. A striking inference may be drawn from the performance of the clarifier in the softening practice, namely, the great reduction in the size of settling basins needed prior to filtration.

"At the Newark plant installed two years ago, regular practice was followed and settling basins holding eight hours of supply were constructed. Based upon the performance of this plant, the Greenville and Piqua designs have reduced the settling basins' capacity to relations of from two to three hours. In the latter design a by-pass of the settling basins has been arranged in order to determine whether or not all of the settling basin may be omitted."

Other installations of this unit, in water softening plants, are at Miami, Fla.; Benton Harbor, Mich.; and Springfield and Hinsdale, Ill.

The equipment for clarifiers is made in sizes from 10 ft. square up to 225 ft. across, in convenient units of 5 ft. increase. Depths may be as desired, or as required by the local conditions of foundation, but a shallow unit will undoubtedly conserve excavation and save in first cost. Where

* New Features of Water Purification in Ohio — Frederick H. Waring, Chief Engineer, Ohio State Department of Health. N. E. W. W. JOURNAL, August, 1926.

all the water must be pumped to the plant, the units can be located above ground and the sludge discharged hydrostatically to the river.

The units are provided with automatic safety switches which shut off the motor and prevent damage to the mechanism should an undue load occur or any foreign object drop into the tank. An indicating overload alarm is also provided, which visually indicates the load on the submerged arms and also notifies the operator, by bell, light, or siren, just previous to the shutting off of the motor, at times of undue load. To further facilitate operation, each unit is provided with a lifting device operated by a chain, which raises the entire mechanism at least twelve inches off the bottom of the tank.

CHLORINE STUDIES AND SOME OBSERVATIONS ON TASTE-PRODUCING SUBSTANCES IN WATER AND THE FACTORS INVOLVED IN TREATMENT BY THE SUPER- AND DE-CHLORINATION METHOD.

DISCUSSION OF PAPER PRESENTED BY NORMAN J. HOWARD* AND RUDOLPH E. THOMPSON†

[*This paper was printed in the September, 1926,* JOURNAL, *page 276. — Editor.*]

MR. NORMAN J. HOWARD. Since the presentation of the paper by R. E. Thompson and the writer at the Providence meeting of the New England Water Works Association held in September last, so many enquiries have been received regarding the new taste elimination treatment at Toronto, that it has been thought desirable to follow up the paper with the following observations.

The super-chlorination treatment was temporarily discontinued on September 12, 1926, due to a shortage of sulphur dioxide, after twelve days' successful treatment under extremely adverse conditions. Treatment was re-commenced on September 28, and applied continuously until December 8, making a total of 84 days' application. The process was stopped at this time on account of the refusal of the Board to sanction the necessary funds for the purchase of equipment and sulphur dioxide. It was decided to carry on with the ordinary chlorination treatment for a period of thirty days, meanwhile observations were to be made on existing taste conditions. Before discussing the treatment during the super-chlorination period, it should be stated that an intensive taste occurred in the city water on the 8th to 11th of December immediately following the discontinuation of the treatment, over forty complaints being received at this time. Generally speaking, the water and meteorological conditions were very unfavorable, it being particularly unfortunate that the treatment was stopped at the commencement of a bad-taste period. During the past six weeks the weather has been more or less favorable and observations made on taste conditions are of very limited value. Nevertheless taste of a mild nature has occurred on each occasion when easterly winds have prevailed over a 24-hour period. Between the 17th and 22nd of January, 1927, weather conditions again became unfavorable and many complaints of taste were received.

At the outset it should be pointed out that the early days of actual operation must be regarded as furnishing the basis of future treatment, and be more or less of an experimental nature, particularly when the extremely difficult operating conditions at Toronto are considered.

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Under the new conditions of treatment the effluents from the mechanical and slow-sand plants are treated separately, and have different contact periods with chlorine. Usually, the ratio of water mixture from these plants is 1:1.5 respectively. The mechanical effluent receives its chlorine as it discharges into the conduit flowing to the city, while the slow-sand effluent is chlorinated in the regulator house immediately before passing into the reservoir where the water, before flowing to the city, is retained for approximately three hours. If each effluent were discharged separately to the city, the mechanically-filtered water would have a minimum contact period with chlorine of $1\frac{1}{4}$ hours while the slow-sand filtrate would have a $4\frac{1}{4}$-hour contact period. This has been one of our greatest problems, as under existing conditions, when the two waters meet, the mechanical effluent has had only twenty minutes contact with chlorine while the slow-sand filtrate has had $3\frac{1}{4}$ hours' contact. Unless the slow-sand filtered water contains a large excess of chlorine which often is unnecessary, the mixing of the two effluents in different proportions results in dilution, which reduces the necessary contact period for the mechanical effluent and may interfere with the effectiveness of the treatment. Observations have clearly shown that mechanically-filtered water in Toronto, must have a definite amount of chlorine and time contact period in the super-chlorination treatment. If as a result of dilution or an insufficient application of chlorine, either of these conditions is interfered with, the treatment is not effective. To overcome the conditions mentioned we have been compelled to apply much larger doses of chlorine to the slow-sand filtrate several hours ahead of anticipated taste, and this promises to furnish the solution to the chief problem so far encountered, but necessarily increases the cost of treatment. Insufficient equipment has also been a difficulty, as at time of high consumption it has been impossible to apply the necessary dosage.

Generally speaking the new process must be regarded as highly successful. The water under treatment was frequently abnormally polluted both chemically and bacteriologically, a condition in Toronto which is always associated with taste. The ammoniacal nitrogen figure rose at times from 0.001 to 0.298 p.p.m. while the B. coli tests gave positive results in 0.001 part of one cubic centimeter.

Taste was reported on four occasions during the period of treatment. In each instance it was possible to correct the condition but not before the entire distribution system had become affected and taste recorded in all parts of the city. On two occasions taste would have been less had the chlorine dose been raised sufficiently high before taste actually occurred, and observations have shown that efforts to economize in chlorine application have usually resulted in the production of taste. It has been noticed that critical taste doses occur. In waters susceptible to taste, large applications of chlorine just below the necessary quantity to destroy taste has the effect of increasing taste. In one series of experiments taste developed following chlorination when 0.25 part of chlorine were added. The taste

got worse with chlorine applications of up to 0.50 part but showed marked improvement when 0.6 part were applied. Increasing the dose to 0.80 part the water became almost undrinkable but improvement took place when 0.90 and 1.0 parts were added. With a dose of 1.25 parts the water became tasteless following de-chlorination. In a sample of water treated with 0.80 part the addition of 0.20 p.p.m. of chlorine caused the water to taste very much worse. This was an important observation as it showed the desirability of not adding chlorine to water which had received an initial ineffective dose. On the other hand the straight application of 1.0 p.p.m. of chlorine had a very beneficial effect.

With a drop in water temperature below 42° C., greatly increased applications of chlorine became necessary, the effective dosage increasing to 2.0 p.p.m. for the mechanically-filtered water and 1.5 p.p.m. in the slow-sand filtered water. Our original experiments indicated that a dose of chlorine would not exceed 1.25 parts with a minimum of one hour's contact. Operating conditions have clearly shown that some other factor interferes with the effectiveness of the treatment under cold water conditions. Residual chlorine studies showed that this condition was seemingly not involved. Actually the figures indicated a decreased rate of chlorine absorption and a necessary increase of sulphur dioxide for complete removal of excess chlorine. It seems highly probable that the decreased biological activity in the cold water prevents the natural destruction or reduction of phenolic bodies in the raw water. Consequently the phenolic concentration is greater and a larger amount of chlorine is required. The increased application of both chlorine and sulphur dioxide during the winter months naturally increases the cost of treatment, but taking the whole year around, our original estimate of cost will remain much the same. When using excess chlorine the practice of pre-chlorination was abandoned as it was found to seriously interfere with taste destruction. After 30 minutes' contact in the mechanical filters the residual chlorine was so reduced in quantity that an insufficient amount remained. It was found impossible to control the dose and consequently the treatment was discontinued.

Researches are being continued and it is hoped that new and valuable material will be available later in the year.

As the result of three months' operation the following summary can be said to represent the observations made:

1. The treatment was effective and conditions greatly improved.
2. Taste occurred at four periods during treatment.
3. Laboratory studies showed that insufficient chlorine was being applied at these times, due in part to lack of equipment and rapid changes in the quality of the raw water.
4. Occasional intermittent pollution of an intensive character makes the treatment uncertain unless continuously high doses of chlorine are applied. This increases the cost of process.
5. Economy in chlorine application is fraught with danger. It may render the treatment ineffective or make the taste conditions worse.

6. Biological activity in warm water assists in taste elimination and allows a reduced application of chlorine being made.

7. In order to be sure of the effectiveness of the super-chlorination treatment in Lake Ontario water under cold water conditions, 2.0 parts of chlorine must be applied to mechanically-filtered and 1.5 p.p.m. to slow-sand filtered water.

8. The mixing of waters containing different quantities of chlorine is inadvisable provided the final dose of chlorine in the mixed water is below the necessary concentration for taste destruction.

9. Adequate equipment considerably over normal capacity is essential to meet rapidly changing conditions.

10. In testing super-chlorinated water for residual chlorine under cold water conditions, at least 10 minutes' contact with ortho-tolidin is necessary to ensure correct readings.

11. Under similar temperature conditions the necessary dose of sulphur dioxide for removal of free chlorine, did not usually agree with the amount indicated as being necessary by the ortho-tolidin test. As much as 50 per cent. excess sulphur dioxide was at times necessary to complete the removal.

12. It was found desirable to remove all residual chlorine in order to be sure that taste did not occur at distant points of distribution. This condition was originally observed in England by Sir Alexander Houston. It is of interest to point out that this condition only applies during periods when the water is known to contain taste-producing substances. Under normal conditions it is unnecessary, even though super-chlorination is being practised.

13. In waters subject to rapid changes in quality close control alone can ensure successful treatment.

14. Improvement in maintaining pressure of liquid sulphur dioxide under high discharge conditions has been effected by placing steam coils in between the cylinders.

CERTAIN ECONOMIC ADVANTAGES ARISING FROM THE PRIVATE OWNERSHIP OF WATER COMPANIES.

BY PROF. ARTHUR S. DEWING.*

[*Read January 12, 1927.*]

The discussion of this subject is not an exposition, it is an argument. It deals with an age-old topic and it confessedly comes to a conclusion. Moreover, there is no attempt to couch the conclusions in any evasive language.

The delivery of water from fountains to the consumers in cities has long been considered a public service. But aside from the technical definition of a public service by statute and court decisions — statutes and court decisions which vary among the States — it is exceedingly difficult to draw an inclusive and exclusive line of demarcation between what is and what is not a public service. We get nowhere by considering a public service that which is a public necessity, for provision markets and clothing shops are quite as essential to communal existence in New England as water works and toll bridges and more essential than street cars and gas works. Yet, except in the programs of the socialist, no one has attempted to turn the actual operation of provision markets and clothing shops over to the beneficient care of our omniscient city fathers. Obviously the definition of the group of economic services which society wishes to raise to the dignity of a public utility must lie, in both theory and in practice, elsewhere than in social necessity. Under our present highly organized urban life the services of farmers and butchers, millers and bakers, water carriers and physicians, and an almost countless roll of other callings perform services which are quite as useful and necessary to our health and existence as half a dozen of the public services which are conventionally denominated as public utilities.

When reduced to its lowest terms it is a kind of organized fear of extortion, which has throughout the ages driven society to regulate and finally to take over and operate certain of these many public services. This fear of extortion is based on the presumption that free competition cannot secure to the public the delivery of these necessities at the lowest price. Closely related to this presumption is the inference that regulation and finally public ownership can better secure the desired end of the lowest price to the consumer.

History affords many different examples of this fear of extortion, with the resulting substitution of regulation for free competition. In the new empire of ancient Egypt there is clear evidence that the services and the charges of the members of castes who prepared the body for burial — the

*Harvard University.

undertakers of thirty-two hundred years ago — were subject to very definite and mandatory regulation. To the inhabitant of Upper Egypt in the days of Rameses and Tutankhamen, the preparation of his body for burial was the preëminently important thing — it must be safeguarded by regulation and state supervision. In Babylon a disease of the eyes was very prevalent, and surgeons who treated it had their fees carefully regulated by the state. In the Christian Middle Ages a great variety of religious services were subject to regulation by a theocratic state; the Church and state of the Pilgrim Fathers subjected the inns of Plymouth, Duxbury, and Eastham to detailed regulation, both as to services and charges. So in every age a society selects certain business activities which it subjects to detailed regulation, not because they alone are necessary for its existence, but because religious prejudice, superstition, fear of extortion, the caprice of an ignorant oligarchy, or mere accident seem to single them out for special protection or special control.

The same circumstances of historical accident determine whether or not society will proceed beyond mere detailed regulation and assume itself the ownership and administration of the public necessity. Coinage, from the first electon slugs of Lydia and the water tortoises of Aegina, has constituted a government business. But the business of supplying water has been sometimes a government business, sometimes a purely private business. In Athens today water is peddled from house to house in big red jars and in relatively large cities of the Thessalian Plain the common city well is the single source of water. Unfortunately for our perspective we have come to assume that the function of supplying water to urban inhabitants is a public function without recognizing that this point of view is the result of a tradition rather than of a train of reasoning. It is the purpose of this paper to subject this tradition to a brief and perhaps superficial challenge.

The two outstanding requirements of a municipal water supply are purity and cheapness. Abundance might be added as a third, but it is, in reality, involved in the other two, for scarcity of water would show itself either in lessened purity or lessened cheapness.

The bearing of municipal and private ownership and operation on the purity of the water supply is not of great moment because of the existence of enforceable and objective tests. Enlightened public opinion has long ago insisted that the private as well as the public water supply should meet conditions and tests prescribed by independent government agencies.

There shall not be or rather there should not be any discrimination in the tests or their interpretation or in the things to be done or not to be done imposed by a health department on a public and a private water supply. Unfortunately, for political reasons the restrictions imposed on the public water supply are often less stringent and less imperative than those imposed on the private company. But this has little to do with the relative merits of the two systems. That the health of the community is equally the concern of the public health authorities, whatever the economic conditions

under which water is supplied, is so obvious and so reasonable that it may be passed over with little comment. We may assume that public regulation and the public health officers are able to impose on the water supply, however owned and controlled, tests designed to maintain a standard of purity that has nothing to do with public or private ownership. The health of the community, therefore, is not ordinarily a factor in the ownership of the water supply.

At the last analysis the ownership of a municipal water supply is one of economics — unsentimental economics. Under private or under public ownership and operation is water delivered to the ultimate consumer with the maximum long run economy? It is important to note that long run is used. The answer to this question is the kernel of the controversy.

The whole subject of the economics of the municipal water supply resolves itself into three closely allied questions. These are the cost at which water can be delivered to the ultimate consumer; the fairness of payment; and finally the provisions necessary to insure an economical future supply. These three questions will be taken up in this order.

There is no twentieth-century miracle which will lift water to the top of a reservoir, dig ditches, and grow cast-iron pipe. Whether the water is lifted by the employees of the city or the private company, whether the ditches are dug by the city men or company men, or whether the dividends for the Cast Iron Pipe Company arise from tax levies or water bills are, at the last analysis, questions that have to be solved in the unsentimental coin of the water consumers. Ordinarily the water consumers hold no brief for individualistic or socialistic theories of government. They are concerned solely with costs.

It is not my purpose to enter into a long discussion of the economy or lack of economy in the two types of ownership. As an operator of private water companies I feel personally convinced that if the city laborer — whom I observe digging ditches along the ancient roads of my home city — should get on the payroll of a private water company, either his intermittent conversations or his pay checks would soon cease. Some time ago I had to have a service pipe put in by the water department of this same city. For purposes of comparison I checked the cost of the city's work with what the same work would have cost if done by one of the water companies with which I was intimately familiar. The economy in favor of the private water company amounted approximately to 32 per cent. Such comparisons indicate little; they are merely suggestive. Detailed studies of costs in municipal plants and privately owned plants have been made many times. The difficulty with these studies invariably is the difficulty of getting analogous cases for comparison. Digging ditches in loose sandy soil is a very different matter from digging ditches in city streets. Each company has its own policy in regard to the kind of service pipes; and a variety of difficulties will occur to everyone and these difficulties make the comparison of little absolute value. It is important to note, however, that it is by no

means conclusive that services performed by the cities are more economical than similar services performed by private companies.

I have attempted to prepare a study to determine the cost to the consumer of municipally operated water-works service and privately owned water service by a process of reduction from the one to the other in the case of two water systems here in Massachusetts. I speak of reduction to the same standard because it is utterly impossible to compare one rate with another owing to the differences of connotation. The private water company must pay taxes and ordinarily charges itself with reasonable depreciation; yet it receives a revenue from the taxpayers for hydrant service. The municipal water plant pays no taxes; it may even pay no interest, the extensions being supplied by city bonds the service of which is included in the tax levy. The municipal plant ordinarily fails to appropriate sufficient and adequate depreciation reserve but it gives, free of charge to the taxpayer, a hydrant service. Obviously in order to make a fair comparison with rates it is necessary to translate the accounting of the municipal plant into the accounting of the private system, or vice versa. If the rate of one is reconstructed in terms of the rate of the other, then some kind of an inexact but suggestive comparison may be made.

Two towns in Massachusetts were selected for an example of such a comparison — one served by a municipal water system and the other by a private water system. The towns are of approximately the same size and inhabited by people of approximately the same economic status; both the water systems reach into rural districts, both represent approximately the same capital costs, both supply approximately the same number of customers and both pump against approximately the same head.

The flat rate charged to the consumer by the municipal system was $12.00, while that charged by the private company was $15.00. Obviously, the consumer of the town-owned system must consider, with satisfaction, his lower rate; and he infers that he is buying water at a lower net cost than the private water company's rate payer. An examination of the town records of the two companies indicates, however, that certain adjustments must be made to both rates to get the net costs to the consumer.

Let us consider first the municipal rate payer's adjustments. The town assesses $5 000 for hydrants and pays $10 910 as interest on its water bonds. If this municipal outlay of $15 910 is divided among the 860 customers, there appears to be a hidden cost of $18.50 per water customer, which the water customer indirectly pays through the general tax levy. Furthermore, his municipal system is steadily depreciating and ultimate renewal must fall on the rate payers of the town. In the case of the private company ultimate renewal must be borne by the private company and the depreciation reserve is absorbed in the consumer's rate. Consequently, to the municipal water rate must be added a depreciation charge. In this case the municipal water plant represents an investment of $272 800. An annual depreciation charge of 2 per cent. — a very moderate charge when

the pumping machinery is included in the investment — would involve an additional "hidden" cost to each of the 860 consumers of $6.20. Adding these together it appears that each consumer of the municipal plant is unconsciously but actually paying $24.70 in addition to the $12.00 he consciously pays his town water department. His net cost is actually $36.70 a year.

Some adjustments, too, must be made to the rate paid by the water consumers of the town having a privately-owned system. Their apparent rate is $15.00 per annum. But the private water company receives, in addition, $45.50 from the taxpayers in hydrant rental. This is $6.30 per customer for each of the 723 customers. On the other hand the private company pays to the Town Treasury in taxes $3 109. This amounts to a kind of rebate to each water consumer — provided, as is not the case, the taxes were evenly distributed among each water consumer — of $4.30. Applying these adjustments to the apparent water rate — an addition of $6.30 for hydrant service and a reduction of $4.30 for taxes — it appears that the water consumer of the private water company is paying $17.00 net. This is in contrast to $36.70 net for the customer of the municipal plant.

I have attempted to make this study for two reasons. One of them is to show that a comparison between the rates charged by the private company and the municipal water supply can be compared only if analogous cases are used and then at best the comparison is only suggestive. The other reason that a comparison of this character is made is to suggest that it is by no means clear that the cost to the consumer of public water is less than that supplied by private water works. If a man owns a great deal of real estate in a city, a large house with extensive grounds, for example, and consumes a relatively small amount of water and if at the same time a part of the running expenses of the water department are borne by the general tax levy, then almost invariably he would pay more for water than he would if the town were supplied by a private company. I can conceive, on the other hand, if, under the same circumstances, where the public water department is supported partly by the general tax levy, a man with a large family of children occupying a few rooms in a tenement house would undoubtedly buy his water cheaper under the municipal system than if the water were supplied by a private company. These are the extremes. The vast majority of people neither occupy houses with extensive grounds carrying heavy taxes nor do they have large families of children in a few rooms of a tenement house. And, too, in this vast majority of people, the rich and the poor, the individualist and the socialist, the costs, in the end, are dependent on the accessibility of a wholesome water supply, on the amount charged to depreciation and reserves, and the relative amount of water used from each faucet. These, and many other considerations, determine, in the individual case, whether the actual water bills are lower under the municipally-owned or privately-owned water supply.

What I hope is clear from these observations is that a comparison of relative consumer costs is extremely difficult to draw. I am not, for a moment, presuming that either from the one or two comparisons suggested here or even from elaborate statistical studies can we reach an unequivocal conclusion which will enable us to assert definitely that the municipal or private water supply gives water to the American citizen at his faucet at the cheaper rate. I wish to emphasize that the comparison at best is extremely difficult. If it is difficult, a great many of the broad generalizations and somewhat superficial phrases sometimes indulged in by the public ownership advocate can be substantiated by facts only after a very elaborate series of studies which, at best, must make certain assumptions that tend to vitiate the reliability of their conclusions even though the statistician holds no brief and indulges in no prejudices.

The second point in connection with the economics of the two types of water supply is the relative fairness of rates to the consumer and rate payer. I suppose one of the outstanding characteristics of the American temperament, whatever its background or whatever its prejudices may be, is a desire to administer all public and quasi-public functions in the spirit of the utmost fairness. Difficulties are usually encountered in the practical application of this principle because of differences in the ideals of individual and social justice but that we all subscribe to the ideal of fairness is, I believe, an American characteristic. I think we should approach the subject of fairness with which the consumer is treated by the private and public water supplies from two angles: first, from the angle of all the citizens and secondly, from the angle of difference of water demand.

Only the large congested cities are devoid of sparsely inhabited areas. When a water main is put along the central street of a town there may be a hundred services to a mile from it and the capital cost to be allocated to each service is relatively small. As the mains reach further and further into the rural areas the capital cost per service increases until ultimately it reaches a point where further extensions into the less inhabited areas are prohibitive at the published rates. Now it is the habit of water companies to charge the same rate over their entire territory covered whether the consumer is at the center or at the periphery, so that we need not discuss relative costs and relative profits between the consumers at different points on the distributing mains. But there is a very marked difference between the area reached by the mains and the area not reached. The inhabitants of the outside area derive no benefits from the water system. Now if the water system is owned by the municipality either one or two things will invariably happen. Either the rates charged to the water consumers will be insufficient to pay for operation and establish reserves. In this case, the deficit must be made up from the tax levy. This is the usual case and we will call it Case One. On the other hand it might be possible that the municipal water rates should be so high that not only do they meet the operation costs, depreciation and reserves but there is a surplus to be paid

back into the Town Treasury — a surplus which reduces the general tax levy. This is Case Two. In Case One the inhabitants beyond the main are not treated fairly, because the taxes on their property are increased by their proportion of the deficit of the water supply. They bear some of the burden of the water system without deriving any benefits from it. In Case Two the people within the area supplied by the municipal water works are not treated fairly because they are charged more for water than the actual costs warrant. Consequently unless a water rate which gives a revenue exactly equal to the costs — an almost impossible thing to do considering the complexities involved — either the rural or the urban consumers are unfairly treated by the water works. Usually the rate is too low (Case One), so that the water department is a burden on the general tax levy. Then not only does the rural inhabitant suffer from larger general taxes but he is forced to pay higher insurance because of lack of hydrant protection. I have a suspicion that one of the insistent problems of our American political and social life is the amelioration of a lot of the rural inhabitants. Not only is this true from the point of view of fairness to him but also from the point of view of social economy. We should do everything to encourage the rural inhabitant to remain on his farm rather than move to the center where conditions are already congested. He should not be taxed in order to help provide a low water rate for the more fortunate urban residents of his town.

There is also another aspect of fairness which affects this question — namely fairness between the large and the small user. If a man pays a small property tax but is a large consumer of water, it is for his obvious advantage to have the rates for water very low and the deficit of the water department borne by the general tax levy. If he is a large taxpayer but a small consumer of water, it is for his advantage to have the water rate as high as possible, so that the profits of the water department may reduce the general tax levy. This creates an unfortunate divergence of opinion based on personal advantage. If one class obtains control over the water department, one policy would naturally be pursued; if the other class, the other policy would be followed. Ideal fairness would require that rates correspond exactly to costs. This is extremely difficult to accomplish as the chances are that the water department will be in control of one factor of the community or the other; and as the class who are small taxpayers but large water consumers ordinarily predominate in numbers their political influence will be such that they will determine the policy of the water department — to the obvious unfair treatment of the other class constituting a minority.

These difficulties are not present with a private water company. Through a long series of court decisions on the one hand and state statutes and public service commission rulings on the other the rate charged by the private company must be such that it corresponds exactly to the costs of operation. This includes taxes, reserves for depreciation and possibly for

future extensions, and a fair rate of return on the invested capital. In other words the water company is required by statute, reinforced by court decisions, to establish rates which correspond exactly to the costs of operation — using the phrase Costs of Operation in its economic sense of including wages to labor, interest on capital, salaries and profits for administration and rental on natural resources. In the long run, from year to year, and from decade to decade, capital, be it through water company stocks or municipal bonds, cannot be enlisted in any enterprise unless these ultimate costs are met.

I wish finally to discuss the third economic aspect of the question which, from certain points of view, is the most elusive and the most important. It is the question of whether adequate future requirements are more assured under private ownership or public ownership. We are asked to judge which system affords the more enlightened long-time attitude toward public welfare. We are living in a capitalistic age. More and more with the development of urban life the individual is dependent for his daily necessities upon the operation of great capitalistic undertakings. The carriage of food to a city, the morning and evening rushes of its workers, and its light and its water all require an enormous capital investment. Not only must this capital provide for the needs of the present but it must be invested with the full understanding of the needs of the future. If there are now only twenty houses along a new road, a small water main may be adequate. If within a couple of years the number of consumers is doubled, the main may be totally inadequate. This change has nothing to do with the ageing of the main. In fact, if the superintendent could be certain that the number of houses would remain constant through the years, there would be no guesswork in determining whether or not to lay a new main and whether it should be large or small.

In this respect, therefore, the question really resolves itself into the question of whether the private company or the public water supply adopts a more enlightened and a more intelligent policy in regard to extensions and improvements. While it is impossible, as it is in the matter of economy of rates, to prove statistically that the private company gives to the public better service, there are certain aspects of the question which are worthy of consideration. The private company can adopt a longer temporal span in which to orient its actions. The personnel of a water board of a city or a town is at best temporary. Politicians come and politicians go, perhaps forgetful that the flow of water must go on forever. Now the pressure exerted upon public boards is always the pressure of temporary economy. Every board wishes to make as good a showing as possible, either to justify its policy or else to hold on to its job. Temporary costs loom large on its horizon, future needs, especially if accompanied by heavy expenditures of not too obvious necessity, are unimportant matters on its horizon. The average taxpayer will back up the water board that spends the least money on the general theory that taxes are always heavy enough and the future

can surely take care of itself. Consequently a hand to mouth policy is invariably adopted. Mains that are too small for a growing section are laid because larger mains bear too heavily on the present costs. New sources of supply are postponed from year to year on the same grounds. As a result the water system is built up of a composite of temporary expedients. If the water board is wise enough to follow the advice of an engineer who is sure of his job over a long period of time, it may counteract this natural tendency of nearsightedness. But the expenditures, seemingly unwarranted, of such a board and such an engineer will not be popular with the taxpayer and the chances are that their administration will be short-lived. We are all human. In national and municipal expenditures we all bless the servant who takes the least present taxes from our pockets. It is perhaps unnecessary and certainly not particularly instructive to mention cases. Not many miles from us here, there are municipal water systems which have been built up through considerable periods of time under the influence of this hand to mouth economy. The citizen so far as his water system and his water rates were concerned was living in a Fool's Paradise. Finally a time was reached when the sins of old water boards and city engineers were all too apparent. Enormous expenditures had to be made to entirely rebuild the water system as a result of the perfectly normal growth of the municipality. In some instances the unusual expenditures could be cared for by ordinary means. In other instances special consent had to be obtained from the legislature to meet the very large new capital expenditures. But, however accomplished, the policy pursued by the previous water boards was clearly inimical to public welfare and, gaged in terms of considerable periods of time, uneconomical and thriftless.

Do not understand me to insinuate that the private water company is a paragon of wisdom. But the private water company is administered necessarily with regard to long period policies. No industry, probably, involves so little return in comparison with the capital required. If any reasonable profit in the industry is possible — and in the long run it is probably as possible here as in any other business — the profit must be obtained through wise forecasting of the needs of the public. Extensions must be built with reference always to future demands. And although the present water takers may be charged a higher rate because of the temporary unprofitableness of the extensions and improvements, in the long run I believe they gain because these extensions and improvements provide benefits over long periods of time. It is this greater span of consciousness, this longer vision which in my mind is the greatest advantage of private over public water supplies. It is the same principle that applies to other great capitalistic undertakings. Railroads must plan their yards and tracks always with respect to the distant future and never with respect to the immediate present. Engineers for the nation-wide telephone monopoly, a private capitalistic business involving the investment of over a billion dollars, must plan with respect to the needs years beyond the immediate

demands. The rates fixed for telephone service include not only the costs of operating the plant at the moment of use but also the costs of establishing the extensions and improvements which will stabilize costs in the future. Were this not done, it would be impossible for the railroad, the telephone company, the electric light company or the gas works to plan so as to be able to meet future demands as they arise. It is this fact that water works are always a future rather than a present business which makes economical provision for the future such an important element in their operation. That the future needs of the community are better in the hands of those who have a great stake in the business rather than those whose stake is the whim of a mercurially-minded electorate is a thesis I have endeavored to maintain.

I have said nothing in regard to the usual points of the discussion such as the sinister influence of politics in business, the shifting the burdens of mistakes onto the shoulders of the uninformed taxpayer, the stultifying of private initiative, the waste and graft of public purchases — all these subjects have been discussed and rediscussed from time immemorial. My argument is based rather on the question of long-time economy of service, and long-time enlightenment, and long-time understanding of public needs.

Discussion.

Charles W. Sherman.* Professor Dewing has given us a most interesting discussion, one which should provide food for thought to all of us.

It seems to me that the most important point that he has made is in accentuating the variety and lack of system in the methods of municipal accounting — perhaps no more in water supply matters than in other municipal accounts, but which are particularly interesting to us — the diversity and lack of completeness which makes it, as he has shown, almost impossible to draw any definite conclusion from any figures readily available or without very detailed analysis, and in some cases based largely on assumptions.

It is a difficult matter to see how that condition can be gotten away from without the supervision of state or other boards which shall prescribe methods of accounting, and which shall do it on such a basis that the figures reported really do mean something.

I am inclined to think that some real progress in that direction has been made, particularly in the State of Maine. There the Utilities Commission has jurisdiction over publicly owned water utilities just as thoroughly as it has over private ones. The publicly owned companies must follow the forms of accounting stipulated by the commission, in the same way, and make the same reports on the same forms as the private companies. Although there are still needs for adjustments and allowances on account of

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the public ownership, in some cases at least, we think they approximate more nearly the same basis of financial returns than those of most of the other New England States. In Massachusetts, even in the cities and towns which have adopted the form of accounting stipulated by the state, the figures are woefully inadequate to show anything that really means very much.

As to what policy, in the long run, is better for a community, whether the utility be publicly or privately owned, it seems to me that there is a good deal to be said on both sides of the case, and that, after all, the final conclusion simmers down very largely to the ability of the owners of the plant — whether it be the municipality or a corporation — to pick capable men and give them sufficient responsibility to run things in a right way.

I have had experience in the past — not in recent years — with certain small water supply corporations not operating in Massachusetts, which were extremely unfortunate in their inception and in their carrying on — so much so that even with engineering operation, which they finally came to, it was impossible for the owners to get even the interest on their bonds, not to mention anything beyond that, and in which the natural result was that their only object was to unload as soon as possible on to somebody else. The interests of the community necessarily took a very secondary place in their minds.

By contrast to the cases cited by Professor Dewing for municipal operation, it may not be inopportune to cite my own town of Belmont, where I happen to be one of the water commissioners. A year ago the chairman of our board died, having then served 27½ years. I was second in term of service, having then served 19 years. The third member had served 18 years. Consequently there was not very much change of policy in that time or very much attempt of the electorate to overturn the board. In our town during my experience, now covering nearly 20 years, there has never been any attempt to play politics with the water department. There has never been the refusal of the electorate to vote a bond issue asked for by the water commissioners, and never but once any attempt to divert funds from the water earnings to other departments. And during that time we have never had occasion to ask for funds from taxes to help run the water department. I admit that our accounting is not on a basis which would enable the true cost of the water to be shown without a great many allowances, and I think that is necessarily true, under our Massachusetts system, of most of our municipalities.

A great many of our towns are paying interest on outstanding bonds very much less than the cost of the works. The difference, which they do not have to include in their water rates, is in a sense in the nature of a provision for depreciation. The retirement of bonds as they fall due under the serial-payment plan now in force in Massachusetts, probably amounts to quite as much, if not more, than would be set aside in a proper depreciation reserve.

There are many things of that kind which would have to be analyzed in detail before we could get down to the true cost of water if it were to be worked out on a scientific accounting basis.

STEPHEN H. TAYLOR.* I have not had the opportunity of looking over this paper, which you asked me to do, but I think it is very interesting and worthy of a great deal of thought.

I think perhaps it is well to bring out the side of the municipally owned plant a little bit, without any personal reflections. I am from a city in which the water works is municipally owned and whose revenue from water rates pays all operating, interest, and water bond charges, as well as having a balance each year to make a moderate amount of extensions.

We collect ten cents per 1 000 gal. for manufacturing, and fifteen cents per 1 000 gal. for all other uses, with a minimum charge of five dollars per year for water, which is a very low rate. Our water system has the highest rating by the National Board of Fire Underwriters and by the State Board of Health. It is without doubt ample for the next 40 or 50 years, showing that our board has looked into the future. The net cost of the plant is about $6 000 000 and the net debt about $1 000 300. We collect no revenue from hydrants, so that the takers entirely support the water system and provide fire protection for the whole city.

Our board has been more or less continuous with very few changes. The superintendent who proceeded me was in office for 40 years. So that the policy of the city has been almost continuous and in good hands. I realize that some cities are not so fortunate, that the water board and the water authorities are changed more frequently, and that the condition which we have will not prevail in all cases.

On the other hand, we can cite privately owned companies which have not been foresighted, as was evidenced by a paper which was read before the Association only a few months ago, in which the water system failed to protect the state owned Normal School and resulted in the city taking over the water system and rebuilding the whole thing, which was absolutely necessary. I think the percentage of well and poorly managed plants will be about the same in privately or municipally owned plants.

So I agree with Mr. Sherman that it resolves itself down to the question of management, whether it is a municipally owned or privately owned plant.

The privately owned plants pay taxes to the community and collect from it a hydrant rental. The municipally owned plant, on the other hand, pays no taxes and generally receives no hydrant rentals. These items probably about offset each other. The privately owned plants usually have bonds or preferred stock outstanding with interest to pay on them and in addition should pay a dividend on all capital invested whereas the municipally owned plant is not expected to pay such dividends but should pay its bond and interest charges in case there are bonds outstanding. It is my belief that under equally good management the municipally owned plant

* Superintendent Water Works, New Bedford, Mass.

should furnish an equally good water supply in all particulars at less cost to the taker, than one privately owned.

HENRY T. GIDLEY.* I was quite interested in this very fine paper, and especially in what was said regarding the private water company, because I happen to be the superintendent of a private water company which I imagine is rather unique from the fact that, although it is a private water company under the laws of this state, all the stock is owned by the Public Library, so that all the interest on the stock is paid to support the library. In that way we pay the library interest on $160 000 at about six per cent., besides paying a tax to the town of about $5 000. It is a small town. So that I hardly think that there is any other private water company that can be compared with it when you figure the cost of water.

Of course politics do not enter into it at all, because the directors of the water company are also trustees of the library. In that way it works out very well because none of the directors or officers of the water company receive any salary except the treasurer, who receives a nominal salary. Although we are right across from New Bedford, where the water rates are very low, as our consumers tell us, if they could figure out as Professor Dewing does here, they would find that the water rates were not so very much higher than they are across the river.

* Superintendent, Fairhaven Water Co., Fairhaven, Mass.

PROCEEDINGS.

JANUARY MEETING.

HOTEL BELLEVUE, BOSTON.

Wednesday, January 12, 1927.

The President, Frank E. Winsor, in the chair.

The Secretary announced that the following had been elected to membership: Sidney S. Anthony, Augusta, Me.; John D. Capron, Burlington, N. J.; Charles W. Shippee, Boston. *Associate:* Layne New York Co., Inc., New York City.

A paper on "Financial Policies of Private Water Companies and Municipal Water Departments," was read by Arthur S. Dewing of Boston. Charles W. Sherman, Caleb M. Saville, Stephen H. Taylor, Henry T. Gidley and T. G. Hazard, Jr., took part in the discussion.

A paper entitled "The Study of Distribution Systems," was read by Lawrence Hough, Division Engineer of the Pitometer Company. The discussion was participated in by Edgar K. Wilson, Charles W. Sherman, Frank A. Marston, Henry A. Symonds, and Professor Dwight Porter.

(*Adjourned.*)

FEBRUARY MEETING.

CHAMBER OF COMMERCE BUILDING, BOSTON,

Wednesday, February 7, 1927.

The President, Frank E. Winsor, in the chair.

SECRETARY GIFFORD. At the Executive Committee meeting this morning the following were elected members: Jacob A. Handy, South Dartmouth, Mass.; Herbert Bradley Crowell, Haverhill, Mass.; Walton Harvey Sears, Arlington, Mass.

The presiding officer wished me to announce that recently the following members of this Association have passed away: Milton H. Bronsdon, Providence, R. I.; Frank A. Mazzur, Boston.

PRESIDENT WINSOR. I will now call on past-president Sanders, who I think can tell us something about some experiments he has made recently in the use of thermit in thawing water pipes.

PERCY R. SANDERS. At the Convention in Providence we listened to a most interesting talk on the use of thermit in removing ice jams from rivers, ice from intakes and also in destroying icebergs. This talk was given by Dr. Howard T. Barnes of McGill University, Montreal. In this talk he expressed a desire to experiment with different forms of thermit in

thawing frozen hydrants, and to do this work in connection with a committee of this Association. I suppose that the president, in common with everybody else, thought that Concord, New Hampshire, was one of the coldest spots in New England, so he asked me to be chairman of the Committee and to suggest two other members. I therefore suggested Mr. Gay, Superintendent of Water Works of Manchester, and Mr. Rice, Superintendent of Water Works of Claremont. We each furnished three hydrants and set them up at Concord. Six of them we set above ground, braced them up, filled them with water and let them freeze. The temperature went down to 10 below zero and every one of those hydrants split from top to bottom. The other three hydrants we set in the ground, and while we did not connect them to the mains, we did fix them up so that we could get pressure onto them.

Dr. Barnes came to Concord last Thursday, and I wish to say that he came wholly at his own expense and that he furnished the materials with which to make the experiments. This is not the final report; it is a preliminary report to show you that Dr. Barnes is keeping good his promise, and that we are trying to do something. I would say that at the meeting of the Committee last Thursday, Mr. Gay of Manchester (the superintendent of the water works) with his assistant, and Mr. Rice of Claremont were present. (See page 79 for report of this Committee.)

A paper on "Poisonous Effects of Copper," was read by Dr. F. B. Mallory, Pathologist, Boston City Hospital.

A paper on "The Effect of Pipes of Different Metals Upon the Quality of Water Supplied," was read by H. W. Clark, Director, Division of Water and Sewage Laboratories, Massachusetts Department of Public Health.

George H. Finneran, Dr. Joseph C. Aub, Robert Spurr Weston, Dr. Herbert D. Pease, P. B. Anderson, Stephen DeM. Gage, Prof. Melville C. Whipple, David A. Heffernan and Herbert C. Crowell, took part in the discussion of these papers.

(*Adjourned.*)

March Meeting.

Chamber of Commerce Building, Boston,
Tuesday, March 8, 1927.

The President, Frank E. Winsor, in the chair.

President Winsor announced that the following had been elected to membership: Frederick Henry Rose, Waterville, Me.; Andrew Koch, Jerusalem, Palestine; Clark D. Abbott, Wellesley, Mass.; Frederick W. Gow, Holden, Mass.

The following members were elected to serve on the nominating committee: Stephen H. Taylor, Frank A. McInnes, George A. King, John P. Wentworth and W. G. Classon.

A paper on "Soil Corrosion and Its Effect Upon Piping as Shown by Tests of the U. S. Bureau of Standards," was read by J. D. Capron, Research Engineer, U. S. Cast Iron Pipe & Foundry Co., Philadelphia, Pa. Messrs. Robert Spurr Weston, Edward B. Story and W. P. Mostello took part in the discussion.

A paper on "Effect of Cement-Lined Pipes Upon the Quality of the Water Supplied," was read by Burton G. Philbrick of Skinner, Sherman & Esselen, Inc., Chemists & Engineers, Boston, Mass. George A. King, Patrick Gear, Dwight Porter, George F. Merrill, Frank A. Marston, Caleb M. Saville, R. W. Esty, H. R. Buck, David A. Heffernan, Joseph A. Hoy, Herbert C. Crowell, H. W. Jacobs, Percy R. Sanders and Charles D. Howard took part in the discussion.

A motion was made by Arthur D. Weston, that the Association convey to the Bureau of Standards the Association's appreciation of the Bureau's work, and the hope that they might be supplied with ample funds to carry it on, which motion, being duly seconded, was passed unanimously.

A motion was made by Caleb M. Saville that a committee be appointed from the Association to consider the matter of the effect of cement-lined pipes upon the quality of the water supplied, which motion, being duly seconded, was passed unanimously.

The following report was made by George C. Brehm, Director of Public Works of Waltham.

Mr. Brehm. Mr. Chairman, there have been several gentlemen here today who have asked me how the bill for the assessment of water mains came out, and I would just like to report that it has been referred to next year's Legislature; and of course that simply means that it can be taken up at any time by the Legislature. But it was referred to next year's Legislature, so that means it is dead for this year, anyway.

On motion of Arthur C. King, duly seconded and passed, a vote of thanks was extended to Mr. Philbrick for the reading of his paper, "Effect of Cement-Lined Pipes Upon the Quality of the Water Supplied."

(*Adjourned.*)

Report of Committee on Thawing Hydrants, of the New England Water Works Association, Appointed December Meeting.

The Committee appointed by the New England Water Works Association at the suggestion of Dr. H. T. Barnes to confer with him on the use of thermit for thawing frozen hydrants held its first meeting in Concord, N. H., on February 3, 1927.

The cities of Manchester, Claremont and Concord each furnished three hydrants of various designs for the tests. These were erected at the Concord Water Works, filled and frozen. Six of these were set wholly above ground and three were placed as they would be in service.

Two methods of thawing were tried: One using a shell containing thermit which was designed to be placed inside the hydrant and melt its way down through the ice; the other consisted of torch containing a special thermit mixture which was designed to apply a flame directly to the outside of the hydrant, or to the interior. This flame enabled heat to be applied directly on the surface at a temperature of 5 000° F.

The experience with the interior melter showed some difficulties which necessitates further studies.

The thermit torch was applied above the surface of the ground on the exterior of the hydrant. Before the heating, these hydrants could not be opened, but in a little over a minute they were readily opened and put in working condition. The hydrant to begin with was solidly frozen and the ice extended probably considerable distance into the ground.

This method of thawing seems to promise such good results that further experiments should be made.

It is well to mention that no injury of any kind to the hydrant was noticed by the use of these methods.

PERCY R. SANDERS, *Chairman.*
Superintendent, Concord, N. H.

FRANK E. GAY,
Superintendent, Manchester, N. H.

JAMES L. RICE,
Superintendent, Claremont, N. H.

HOWARD T. BARNES,
Professor Physics,
McGill Univ., Montreal, Canada.

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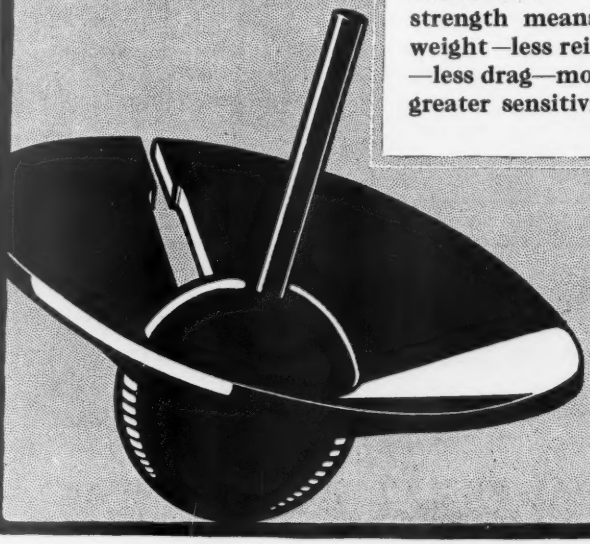

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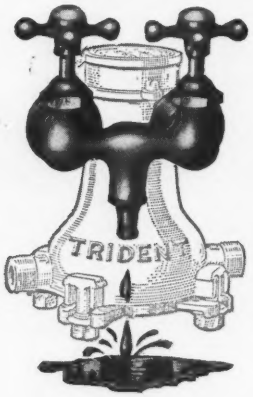

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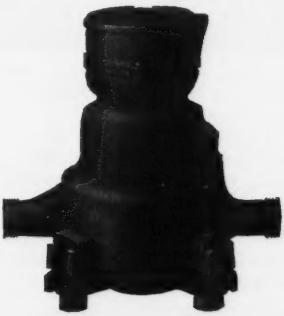

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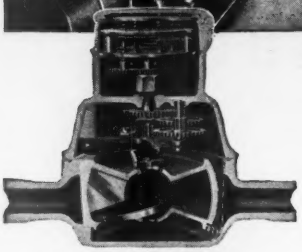

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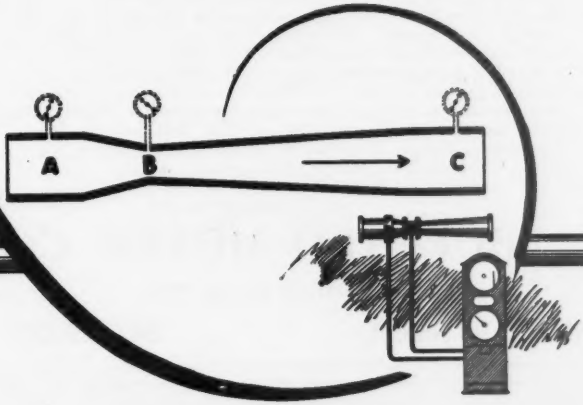

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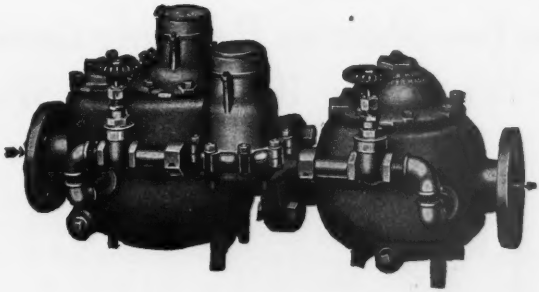

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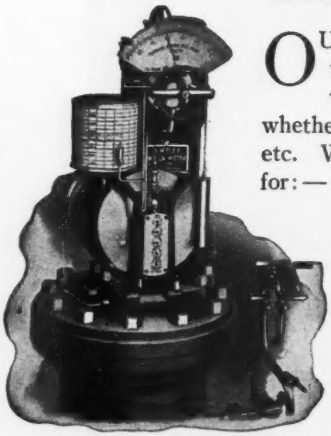

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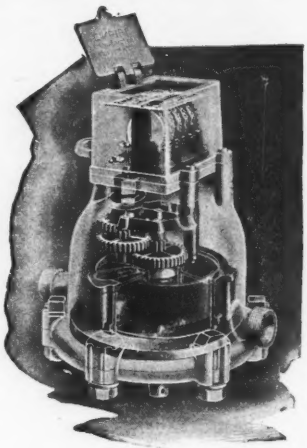

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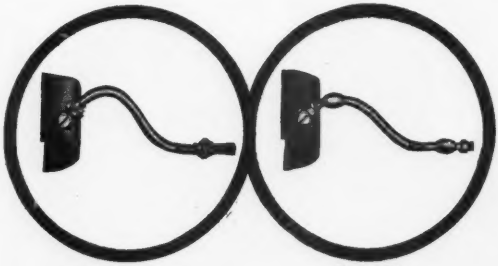

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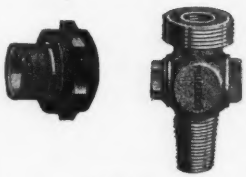

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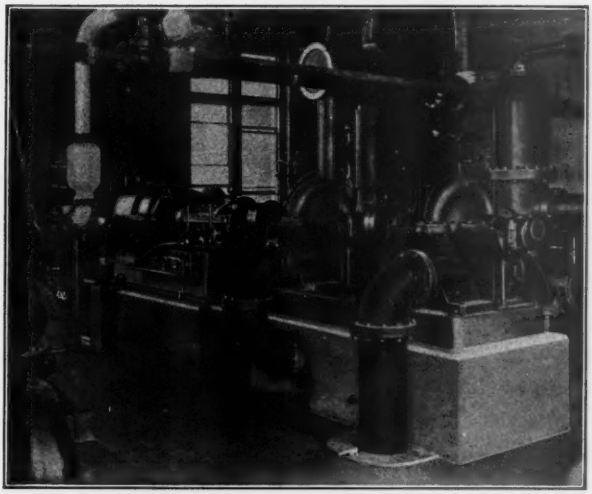

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Town of Andover.
Two Motor Units.

Metropolitan District Commission.

Quincy: Compound Engine Unit.

Reading: Two Motor Units.

Ward Street: Uniflow Engine Unit.

City of Hartford.
One Motor Unit.

City of Lynn.
Four Motor Units.

Town of Milford, N. H.
Two Motor Units.

Town of Amesbury.
Two Motor Units.

HAYES PUMP AND MACHINERY CO.

94 PEARL ST., BOSTON, MASS.

Pumping Plant Contractors

CENTRIFUGAL, POWER, STEAM PUMPS

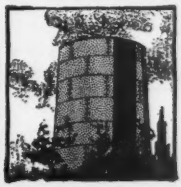
STEAM TURBINES
WATER WHEELS

ELECTRIC MOTORS
OIL ENGINES

RAY ENGINEERING COMPANY
136 FEDERAL STREET
Boston, Mass.

Power Plant Equipment
Steam and Heating Specialties

For new pumping equipment guaranteed by people who will make good, phone, wire or write the above.
Sales Agents for UNION STEAM PUMP CO.



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Water Tanks
Gas Holders
and all other metal surfaces need the protection of
DIXON'S
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PAINT
BOOKLET NO. 87-B
JOSEPH DIXON CRUCIBLE CO. Jersey City, N. J.

WE announce our appointment as Sales Representatives of DAYTON-DOWD COMPANY, of Quincy, Ill., Manufacturers of Centrifugal Pumping Machinery. After exhaustive investigation, we present this line of equipment to the Trade in New England as being of the highest grade and thoroughly modern in design and manufacture.

We are prepared to furnish DAYTON-DOWD pumps in all sizes and for all classes of service, in steam, motor, gasoline and belt drive types, and solicit your inquiries, assuring you of our best efforts in your sales and service requirements, and of our appreciation of your continued confidence and patronage.

POWER EQUIPMENT CO.

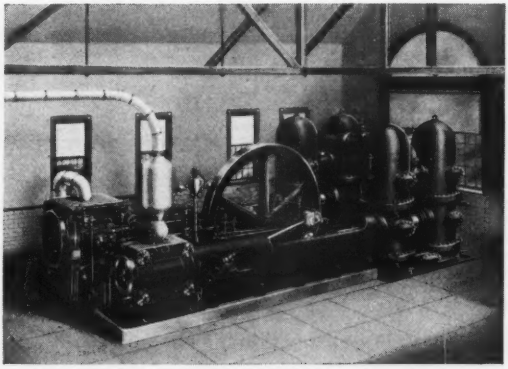
131 State Street, **Boston, Mass.**

MURRAY IRON WORKS CO.

(INCORPORATED 1870)

BURLINGTON, IOWA, U. S. A.

Builders of High Duty Pumping Engines



Murray High Duty Crank and Fly Wheel Pumping Engine, Opposed Type

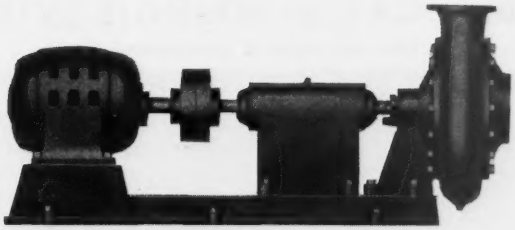
Engineers, Iron Founders, Boiler Makers

Corliss and Una-Flow Engines

Water-Tube, Fire-Tube and Internal-Furnace Boilers

Builders of Complete Power Plants

PLEASE SEND US YOUR SPECIFICATIONS AND CALLS FOR BIDS



Fairbanks-Morse Horizontal Trash Pump direct-connected to Fairbanks-Morse Ball-Bearing Motor

Now a great advance in sewage pumping

For the first time a pump has been designed that will handle fluids containing the fibrous and stringy matter found in sewage — without clogging, without preliminary screening, and without the excessive power consumption that characterizes the less satisfactory open impeller type of pump.

The secret of this pump's success lies in the design of the simple two-blade impeller. The blades of the impeller have well-rounded entering ends and are well filleted with the shrouds or sides. Thus a rag or other trash does not find sharp projections on which to catch and cause clogging. Since the impeller is the enclosed type, foreign matter, in passing through, does not come into contact with stationary side plates, but is promptly discharged through one of the large ports into the pump case. In this way power is conserved and efficiency increased.

This pump was designed by Mr. A. B. Wood who has been serving the city of New Orleans and other municipalities in the capacity of consulting engineer. It was originated by Mr. Wood to cope with the very unusual sewage problems found in New Orleans and met with immediate success.

Fairbanks-Morse Trash Pumps are made in two types, horizontal and vertical. They are ruggedly built to cope with severe service and at the same time they possess such refinements as ball bearings, smoothed fluid passages, and other marks of quality construction.

Ask for bulletins giving complete details.

FAIRBANKS, MORSE & CO., Chicago

28 branches in principal cities at your service.

FAIRBANKS-MORSE

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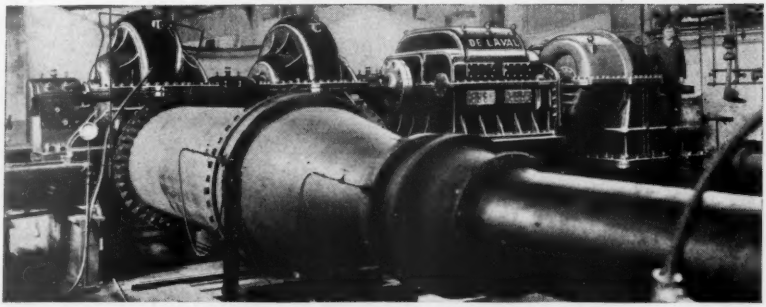
DE LAVAL

CENTRIFUGAL PUMPING EQUIPMENT

is the accepted standard for

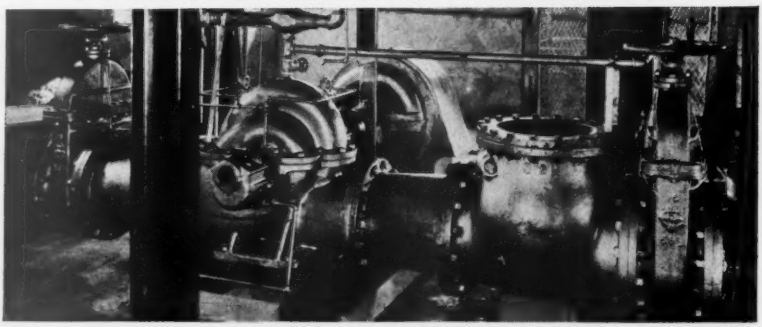
MUNICIPAL WATER WORKS



WESTERN AVENUE PUMPING STATION, CHICAGO.

The largest Municipal steam turbine driven centrifugal pumping unit in the world delivering 75 million gallons per day against 150 feet head.
City of Chicago has fourteen large DE LAVAL pumping units.

TYPICAL NEW ENGLAND INSTALLATION



MILLVALE STATION, HAVERHILL, MASS.

New 7 million DE LAVAL motor-driven pump including the furnishing and erection of transformers and switchboard equipment. On test after installation this pump delivered water at rate of 7,800,000 gallons per day. Another DE LAVAL unit is on order for Kenoza Station, Haverhill.

Recent DE LAVAL municipal water works contracts include New England installations at Canton, Mass., and Millis, Mass.

Ask for De Laval Publication.

TURBINE EQUIPMENT CO. *of* NEW ENGLAND

CHAMBER OF COMMERCE BUILDING

80 Federal St., Boston

NEW ENGLAND REPRESENTATIVE FOR

DE LAVAL STEAM TURBINE COMPANY

Trenton, N. J.

The floods are coming!—

PHOTO BY NASHVILLE AERONAUTIC CORP.

THE CUMBERLAND RIVER IN FLOOD, NASHVILLE, TENN.

—Will you be ready?

THIS spring—as in all other springs—the floods will come. Rivers will overflow.—Surface water supplies will be excessively polluted.—Ground water levels will rise.—Well waters will become contaminated!

Will you be ready?

Will you have a spare W&T chlorinator—and a supply of Liquid Chlorine on hand to render emergency service? Will you be ready to chlorinate that polluted water and avoid the sure toll of pestilential disease?

Water sterilization—always important—is absolutely vital in times of flood.

But why wait for the flood?

Continuous chlorination costs but one cent per head per year and absolutely prevents water-borne disease.

There is no cheaper public health insurance.

"The only safe water is a sterilized Water"

WALLACE & TIERNAN

COMPANY, INCORPORATED

Manufacturers of Chlorine Control Apparatus

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Founded 1853 Incorporated 1863

MERRIMAC CHEMICAL 1863 COMPANY

FILTER ALUM

Aluminum Sulphate

A basic, uniform product which has been used successfully by the leading water filtration plants in New England for many years.

Our location and shipping facilities place us in a position to offer insurpassable service and make us the logical source of supply for all filter plants in New England.

The aid and advice of our technical staff has often proved of great value to our customers. It is always at their service.

MERRIMAC CHEMICAL CO.

148 STATE ST., BOSTON, MASS.

Works:

EVERETT, MASS. WOBURN, MASS.

PRECALKED JOINT PIPE

Can be laid three times as fast as ordinary pipe, for half the labor. B. & S. type. Sand cast. Precalked Fittings also.

McWane Cast Iron Pipe Company Eastern Office 819 Bankers Trust Bldg. Philadelphia

New England Representatives:

FRED A. HOUDLETTE & SON
93 Broad Street, Boston
Eastern Mass., Me., N. H.

BUILDERS IRON FOUNDRY
Providence, R. I.
R. I., Conn., Vt., Western Mass.

GRIP PIPE FITTINGS

Connect without threading

As an Emergency Pipe Clamp

Before

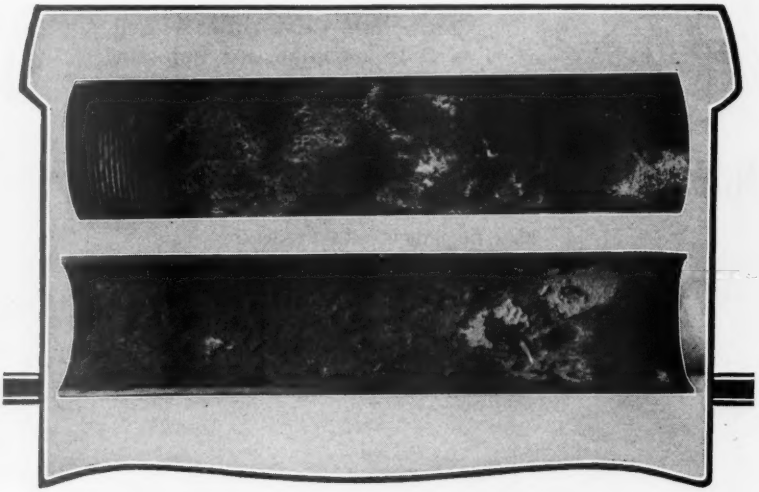
After

Makes Possible an Immediate Repair. Saves Both Time and Money

MANUFACTURED BY

WARE COUPLING & NIPPLE MFG. CO.

WARE, MASS., U. S. A.



40 Years Old—Still Serving!

In the life of a pipe line, forty years is a long time — particularly if it is spent underground, subject within and without to corrosive onslaughts.

The pipe that can stand it is the pipe for service lines. That genuine wrought iron pipe has the necessary endurance is clearly demonstrated by service records all over the country of which the above photograph is an interesting example.

Here is a two-foot section from a line laid in 1886 by the Atchison Water Co. It is still good. It was removed simply to admit a valve. The line as a whole is in its 41st year of constant, uninterrupted service.

For sixty years, Byers has made pipe from genuine wrought iron. Its quality today is no less than that which has already defied rust for two, even three generations. Such, surely, is the ideal pipe for service lines.

A. M. BYERS COMPANY

Established 1864 **Pittsburgh, Pa.**

BYERS PIPE

GENUINE WROUGHT IRON

W. B. Hubbard & Sons Co.

FRANK W. HUBBARD, President-Treasurer
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176 Oliver Street, Boston, Mass.

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SUCCESSORS TO
GEORGE E. GILCHRIST CO.

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Heating and Plumbing Supplies
Steel, Wrought Iron and Brass Pipe
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Hoffman Valves and Controlled Heat Equipment

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BOSTON PIPE & FITTINGS CO.

WHOLESALE JOBBERS

Byers Genuine Wrought Iron Pipe

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COMPLETE LINE OF WATER WORKS SUPPLIES

273-279 CONGRESS ST., BOSTON

We Carry in BOSTON STOCK for Immediate Shipment

CAST IRON BELL AND SPIGOT WATER PIPE AND FITTINGS
FLANGED PIPE in full and short lengths
WROUGHT PIPE

FRED A. HOUDLETTE & SON
(Incorporated)
93 Broad Street, Boston, Mass.
Quotations furnished promptly for shipment from Foundry

CEMENT LINED SERVICE PIPE

With Specially Adapted Lead-lined Fittings

Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

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LYNN, MASS.

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Manufacturers of and Dealers in
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Byers' Wrought Iron Pipe
Service and Valve Boxes
Cast Iron Pipe and Fittings

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Telephone, Liberty 1350

R. D. WOOD & CO.

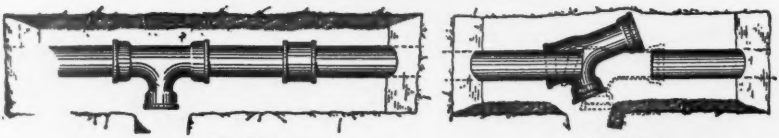
400 CHESTNUT STREET, PHILADELPHIA, PA.

Engineers, Iron Founders and Machinists

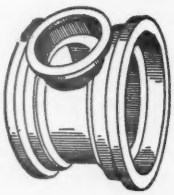
HYDRAULIC VALVES and MACHINERY

Cast Iron Pipe

CUTTING-IN TEES



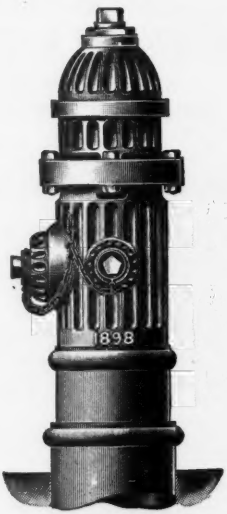
Old Way *Our Way*



Connections economically and easily made with one fitting. Saves sleeve, cuts, lead and unnecessary work and material.

"Reduced Specials"

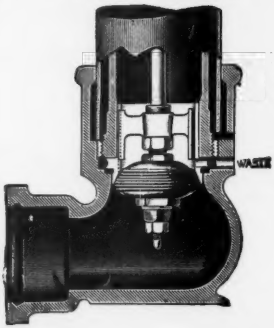
Cost of fittings reduced from 25% to 50%. Full strength. Deep bells. Convenient to handle. Sold by the piece.



Mathews Fire Hydrants

A half century of use has established their reputation as being the most economical, durable and simple hydrant.

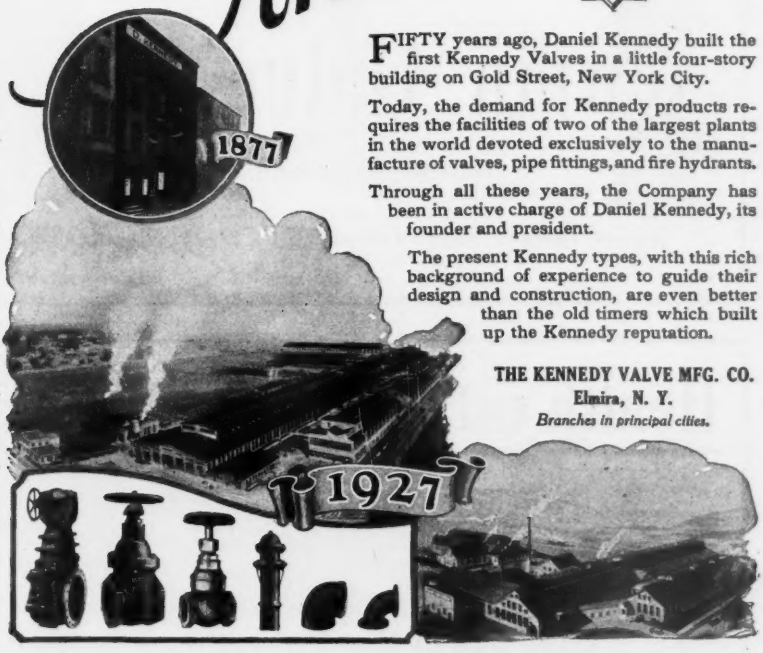
Number in use exceeds total of all other makes combined.



Gate Valves

R. D. WOOD & CO. STANDARD
DOUBLE DISK
ANTI-FRICTION
EXTRA WEIGHT, FINISH
AND MATERIAL

50th Anniversary



FIFTY years ago, Daniel Kennedy built the first Kennedy Valves in a little four-story building on Gold Street, New York City.

Today, the demand for Kennedy products requires the facilities of two of the largest plants in the world devoted exclusively to the manufacture of valves, pipe fittings, and fire hydrants.

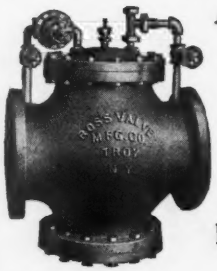
Through all these years, the Company has been in active charge of Daniel Kennedy, its founder and president.

The present Kennedy types, with this rich background of experience to guide their design and construction, are even better than the old timers which built up the Kennedy reputation.

THE KENNEDY VALVE MFG. CO.
Elmira, N. Y.
Branches in principal cities.

KENNEDY

VALVES~PIPE FITTINGS~FIRE HYDRANTS



Automatic Pressure Control Valves
Feed Water Filters
Portable Fire Hydrant Heads
Hydraulic Engines
Hydraulic Booster Pumps

ROSS VALVE MFG. CO., INC. TROY, N. Y.
ESTABLISHED 1879

Coffin Valve Co.

NEPONSET, MASS.

Sluice Gates, Gate Valves and Fire Hydrants

Health and Protection First

Water delivered through dirty pipes
may be a MENACE.

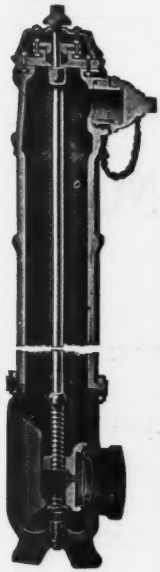
Incrusted water pipes mean inefficiency
and loss of Fire Protection.

We Guarantee the Results of Our
Method of Cleaning.

WRITE US.

National Water Main Cleaning Co.

50 Church Street New York City



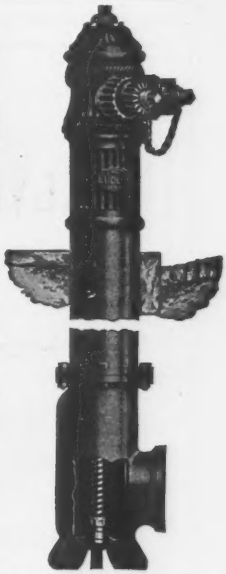
LUDLOW VALVE MFG. CO.

MANUFACTURERS OF

VALVES and FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.

The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.



DOUBLE AND SINGLE GATE **VALVES,**

ALSO CHECK **VALVES,**

FOOT **VALVES.**

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.

☞ SEND FOR CIRCULARS ☜

OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

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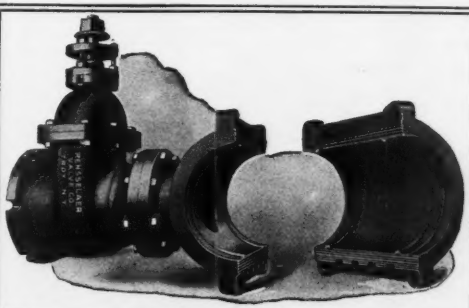

Rensselaer Tapping Sleeves

were brought out to meet a growing demand for a "BETTER" Tapping Sleeve. They were designed to suit conditions met in actual practice.

They can be used with all standard makes of Tapping Machines.

POINTS OF
SUPERIORITY

Have two lead rings.

Require less lead for calking.

Iron washers not required.

Bolting flanges are made full length of sleeve, giving great strength.

Have greater thickness of hubs on ends.

Easier to center on pipe before pouring lead.

Cost less to install.

Book No. 11 gives full information.

Ask for prices.

CHARLES L. BROWN
New England Sales Manager, Lock Box 2, Northboro, Mass.
RENSSELAER VALVE COMPANY, TROY, N.Y.

THE CHAPMAN VALVE MANUFACTURING COMPANY

Manufacturers of

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EDDY VALVE CO.

WATERFORD, NEW YORK U.S.A.

PATENT RUBBER FACED

EDDY FIRE HYDRANT

Section of Taper Seat-Valve.

Hydrant with Independent Nozzle Cut-off.

Section of Parallel Seat-Valve.

Section of Vertical Check-Valve.

Section of Vertical Foot-Valve.

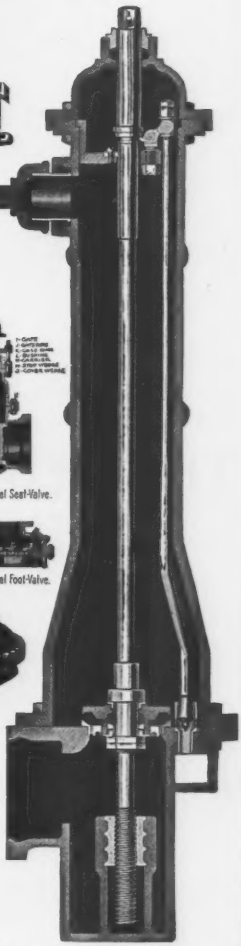
Horizontal Check-Valve.

Vertical Foot-Valve.

Hydrant with Water Crane Attachment.

Indicator Post.

Water Crane with Automatic Drip Valve.



VALVE OPEN - DRIP CLOSED.

All Goods made by the EDDY VALVE COMPANY are manufactured exclusively at WATERFORD. N.Y. U.S.A.

VALVE CLOSED - DRIP OPEN.

EMAUS PIPE FOUNDRY,
DONALDSON IRON CO.,

MANUFACTURERS
...OF...

CAST IRON PIPE

...AND ..

Special Castings for Water and Gas.
Also Flange Pipe, Street Castings,
Manhole Heads and Covers, etc.

J. G. EBERLEIN, President and Treasurer.
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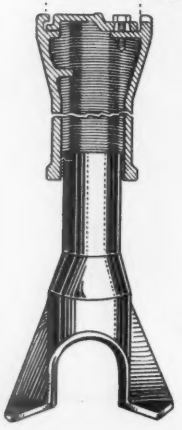
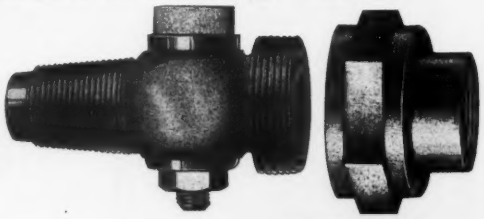
EMAUS,
LEHIGH COUNTY, PA.

The "BEST" Cast Iron Curb Box

Top section is interchangeable with the "Slide Type" Buffalo Box



No change necessary in wrench or shut off keys



"CALDWELL" Water Works
Brass Goods, Curb and
Valve Boxes

None better and few as good

GEORGE A. CALDWELL CO.
Mattapan Square
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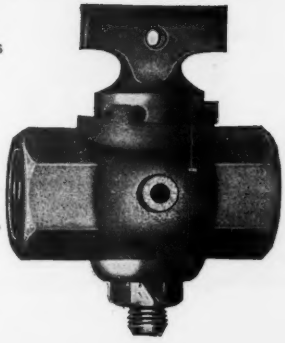

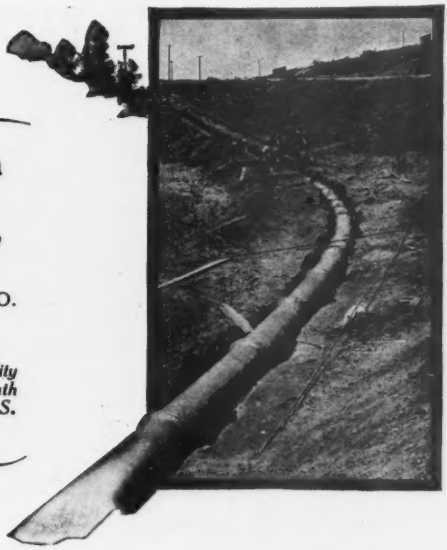

Installation at Spartanburg, South Carolina

SOLOMON-NORCROSS CO.
Consulting Engineers
Atlanta, Ga.

Illustration shows the possibility of laying long easy curves with full length bell and spigot U. S. Cast Iron Pipe.

This installation showed less than 12% of the allowable leakage

Makers of deLavaud Centrifugal Cast Iron Pipe

LEAKAGE TEST ON CAST IRON SUPPLY MAIN

Date of test	Dia. of pipe	Length tested miles	Duration of test hours	Initial pressure lbs. per sq. in.	Final pressure lbs. per sq. in.	Gals. water necessary to restore initial pressure	Leakage per inch dia. per mi. per 24 hrs.
5-7-26	24	2.77	2.0	70	70	50	9.0
5-6-26	27.56	7.57	2.0	40	40	200	11.52

Final tests, constant pressure maintained

Write for details of the service we maintain for the assistance of Construction Engineers

United States Cast Iron Pipe and Foundry Company

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Burlington, New Jersey

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Chicago
Birmingham
Buffalo
Cleveland
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EAST ORANGE, N. J.

Manufacturers of

Tapping Machines, Fire Hydrants, Water Gates,

Economic Lead Furnaces,

Corporation and Curb Cocks, Brass and Aluminum Castings.

Also General Supplies for Water and Gas Works.

Write for Catalogue.

NICHOLAS ENGEL

JOHN FOX & CO.

CAST IRON

WATER & GAS PIPES

FLANGE PIPE

Special Castings, Fire Hydrants, Valves

General Foundry and Machine Work

WOOLWORTH BUILDING 233 BROADWAY

NEW YORK CITY

HIGHEST AWARD, GOLD MEDAL,
ST. LOUIS EXPOSITION, 1904

Over 100 Water Departments

use

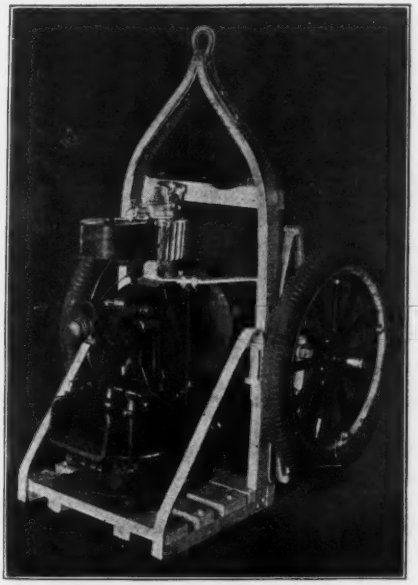
LEAD-LINED IRON and TIN-LINED PIPES

for their service connections

MANUFACTURED BY

Lead Lined Iron Pipe Company

Wakefield ═══ Mass.



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TRAILER PUMP UNIT

IS

Light
Compact
Efficient

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EDSON MFG. CORP.
375 BROADWAY
BOSTON

Warren Foundry and Pipe Co.

(Formerly Warren Foundry and Machine Co.)

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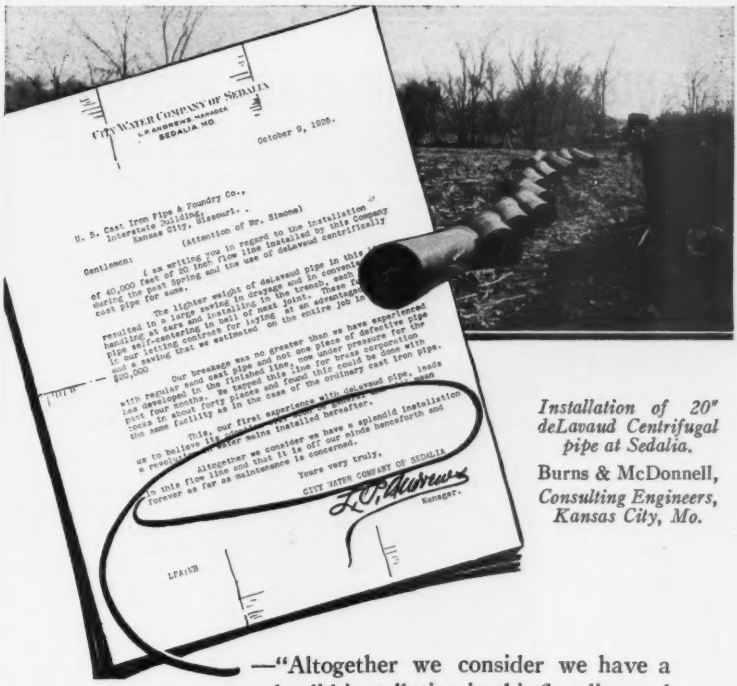

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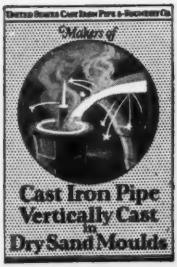

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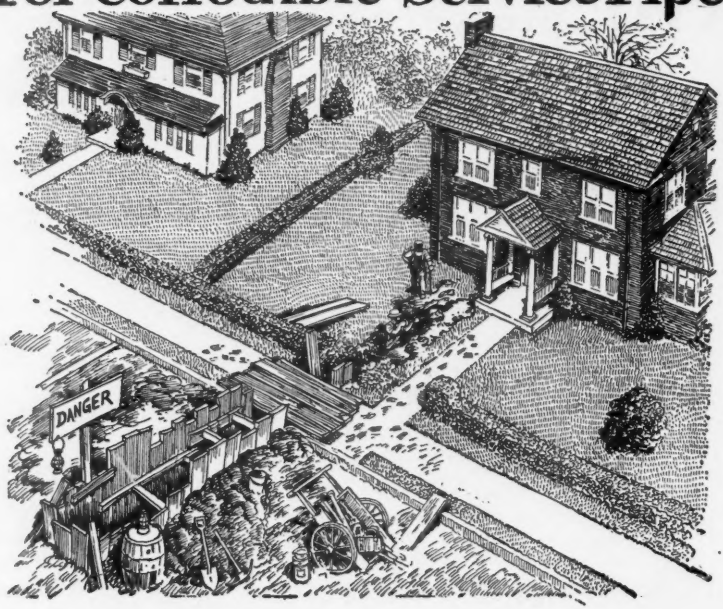

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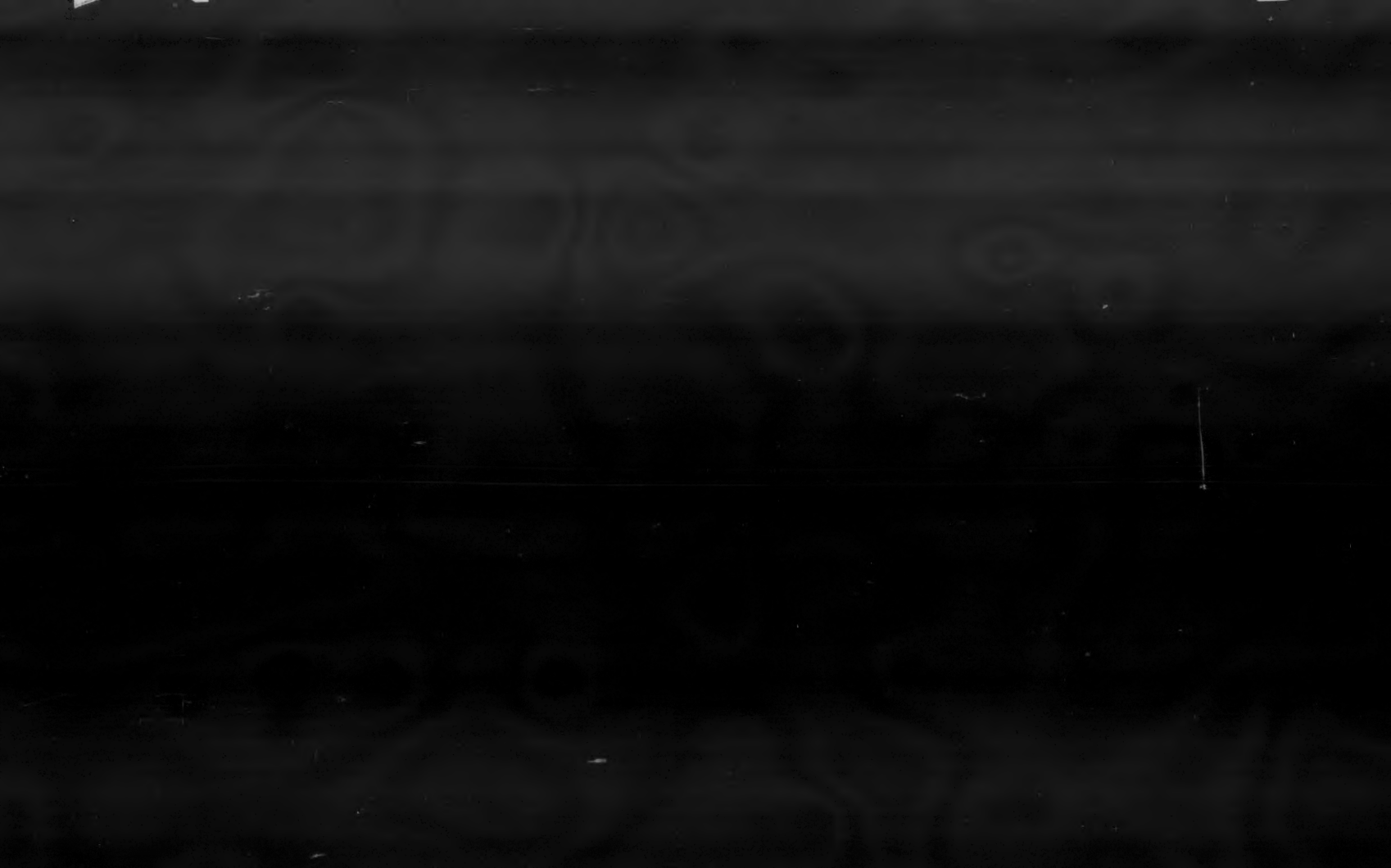

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